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PHYSICAL PROPERTIES OF PHILIPPINE CONCRETE AND CONCRETE AGGREGATES [1]

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Among other activities, during the past ten years, the materials testing laboratory of the Bureau of Science has been conducting tests on concrete made for the Government in different parts of the Archipelago. Not only has this laboratory tested specimens of concrete that have been cast on the building site under typical field conditions, but it has sometimes made preliminary laboratory tests of the same aggregates so that a comparison of the strength of concrete made in the field with that of concrete mixed under carefully controlled laboratory conditions is possible. However, it should be mentioned that the Government has lately erected numerous concrete structures throughout the Islands without making a previous laboratory examination of the aggregates, and even without casting test specimens during the process of construction, so that the results recorded in this paper, unfortunately, are fragmentary. Then again, some of the data obtained by this laboratory were so lacunose that their inclusion here is not warranted. For instance, the Bureau of Science materials testing laboratory has occasionally received concrete test pieces without marks of identification as to age, quality of the mixture, aggregates and cement used, or the structure represented. As it is, I have included tests of concrete made of aggregates whose precise origin is unknown. Sufficient data, however, are given in these instances to sanction publication. Nearly all of the test specimens made in the field were sent to the Bureau of Science by

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the district engineers directly in charge of Bureau of Public Works building projects throughout the Philippines. A few of the field test specimens represent concrete that has entered into the construction of some of Manila's modern business edifices, such as the Manila Hotel, the Masonic Temple, and the Chaco Building. An interesting series of results was secured from test specimens cast in the field during the construction of the United States Army pier in Manila.[2] These results are especially noteworthy in that they show that the careful selection of aggregates, a close supervision of all mixing operations, including the proportioning of the cement, sand, water, gravel, and crushed stone, together with conscientious inspection of the process of putting the concrete in place, so as to compel sufficient spading and tamping of the mix, will under field conditions yield a concrete that is as strong as concrete made from the same materials in the laboratory.

The number of tests recorded totals 1,677. In Table 1 is shown the number of concrete specimens, classified according to provinces that submitted aggregates or test pieces. This table will give some idea of the amount of constructional activity carried on by the Government, throughout the Philippines, during the past decade.

Preliminary to the erection of concrete structures built under the supervision of the Bureau of Public Works, it has been customary to send to the Bureau of Science, for testing, samples of sand and gravel occurring as near as possible to the building site, and at the time thought by the engineer to be the best available material for the work contemplated. The samples of aggregates arrived at the materials testing laboratory packed in gunny sacks, cartons, wooden boxes, kerosene cans, and cement barrels, and ranged in quantity from barely sufficient to make six briquettes and one or two 6-inch cubes, to a barrelful (about 3.8 cubic feet) each of sand and gravel or crushed stone. In general it may be said that the samples were too small, and whether they were truly representative of the deposits or not is problematical. In several instances, tests

[2] For these specimens I am indebted to Mr. George H. Bevin, C. E., general superintendent of construction, Quartermaster Department, United States Army, who turned over to the Bureau of Science one hundred seventy-two 6-inch concrete cubes that were taken from batches used in making the piles, braces, and floor of the Quartermaster's pier. Fourteen cubes were tested and the cubes remaining are being preserved for long-time tests, a portion under the eaves of the laboratory roof, and the other portion in a steel cage submerged in the salt water beneath the pier.

of aggregates had to be postponed because the material sent was insufficient, thus entailing a delay of several weeks; sometimes the samples never came, and construction proceeded without a preliminary test of the aggregates. Such conditions are regrettable. The purpose of conducting tests on concrete aggregates is to eliminate, at the minimum of expense, unsuitable materials. Unfortunately it has not always been possible to carry out the recommendations of this laboratory; and there are instances on record where fine aggregates, entirely unfitted for concrete construction, have been used, often with disastrous results.

TABLE 1.—*Number of concrete specimens, classified according to provinces submitting aggregates or test pieces.*

Province.	Specimens tested.
Leyte	256
Manila and vicinity	242
Bulacan	229
Iloilo	156
Cebu	88
Samar	78
Cavite	73
Occidental Negros	68
Laguna	52
Albay	49
Capiz	47
Pangasinan	32
Bohol	27
Tarlac	26
Cotabato	22
Marinduque	20
Ilocos Norte	18
Ilocos Sur	18
Antique	18
Rizal	16
Sorsogon	16
Isabela	16
Oriental Negros	14
Batangas	13
Tayabas	13
Surigao	12
Zambales	12
Bataan	11
Misamis	10
Nueva Ecija	8
Zamboanga	8
Pampanga	4
Palawan	3
Jolo	2
Total	1,677

Upon arrival at the laboratory, the samples of sand and gravel were first thinly spread on a concrete platform and then rapidly dried by exposure to the heat of the sun, which at sea level in a tropical country is great. When dry, the aggregates were ready for testing. Complete sand tests in this laboratory comprise the determination of percentage of voids, apparent specific gravity, granulometric analysis, comparison of tensile and compressive strengths of 1 : 3 mortar with those of 1 : 3 Ottawa sand mortar, and approximate mineralogical composition; but sometimes not all of these tests were performed. Examinations were conducted in conformity with requests made by the Bureau of Public Works and, as Table 2 shows, are not complete. Ten years' testing of sands for concrete work has shown that very little practical value has been derived in the Philippines from knowledge of percentage of voids, apparent specific gravity, and mineralogical composition data, and that for ordinary routine examinations these tests might very well be omitted, since they tell us nothing regarding the compressive strength of the mortar or mortars yielded by the sand. The compressive strength of mortar is, after all, of paramount importance to the designing engineer; with the exception of granulometric analysis, all other tests play a very inconspicuous rôle in determining the suitability of a sand as a concrete aggregate. The size of the grain and the gradation of grain sizes, more than any other factors determine the compressive strength obtainable from a sand when mixed with Portland cement; so that the granulometric analysis of a sand, in nearly all instances, forms a valuable, practical criterion of the compressive strength.

What has just been said with respect to sand may also be applied to gravel and crushed stone, which constitute the coarsest components of concrete. Specific gravity, percentage of voids, granulometric analysis, and mineralogical composition data are of secondary importance. Table 3 gives the granulometric analyses of some Philippine gravels.

The most important test of gravel in ordinary routine investigation consists in actually making a series of concrete mixtures with this coarse aggregate and then ascertaining the compressive strength of the resultant test specimens. The proportions usually designated by the Bureau of Public Works are the standard 1 : 2 : 4, 1 : 2.5 : 5, and 1 : 3 : 6 mixtures; occasionally requests for other mixtures are received.

LABORATORY TESTS OF AGGREGATES USED IN CONCRETE

Percentage of voids.—A graduated cylinder about 7 centimeters in diameter with a capacity of 500 cubic centimeters was used in determining the voids in the sand. A small quantity of the dried sand was placed in the cylinder and compacted by striking the cylinder lightly on a cloth pad. About twenty blows were given and successive additions of sand compacted until the cylinder was filled to the 500 cubic centimeter mark. It is important to compact all sands to the same mark in order to secure reliable results. The difference between the weight of the cylinder containing the sand and that of the empty cylinder gave the weight of the 500 cubic centimeters of dry compacted sand. Knowing the specific gravity of the sand, the actual volume occupied by the sand grains may be easily calculated by substituting the proper values in the formula:

$$\text{Volume} = \frac{\text{Mass}}{\text{Specific gravity}}$$

If the true volume of the sand particles be now subtracted from the apparent volume as measured in the graduated cylinder, the difference will represent the void space in 500 cubic centimeters of sand. The void space divided by 500 and multiplied by 100 will give the percentage of voids.

The method used for determining the percentage of voids in the coarse aggregate (gravel) is analogous to that employed in connection with the sands and screenings. On account of the larger size of the grain a more spacious and less fragile container was used for weighing a compacted volume of the aggregate. A wooden box with inside lineal dimensions of 15 centimeters was filled with gravel, which was compacted by subjecting it to gentle percussion. The difference between the filled box and the empty box gave the mass of the compacted aggregate contained within a space of 3,375 cubic centimeters. Knowing the mass and the specific gravity of the gravel, it is an easy matter to calculate the true volume of the constituent pebbles by means of the formula already mentioned. The true volume of the gravel subtracted from the apparent volume (3,375 cubic centimeters) gives the void space, and this in turn divided by the apparent volume and multiplied by 100 gives the percentage of void space.

TABLE 2.—*Physical tests of Philippine sands.*

Tracing No.	Province or origin of sand.	Percentage by weight of sand passing through sieve No.— 10.	20.	30.	40.	50.	80.	100.	200.	Specific gravity.	Voids.	Tensile strength in pounds per square inch of 1:3 mortar briquettes. Ottawa sand. 7 days.	Ottawa sand. 28 days.	Sand submitted for test. 7 days.	Sand submitted for test. 28 days.
	ALBAY.										*P. ct.*				
1	Unknown	88	67	41	32	19	6	4	------	2.72	40	267	325	217	246
2	Quinale River	85	55	28	17	10	1	0.7	------	2.69	42	354	402	246	352
3	Guinobatan River	97	70	39	26	12	2	0.5	------	2.72	48	339	405	214	259
4	Unknown	79	53	36	28	16	5	2	------	2.80	37	------	------	------	------
	BOHOL.														
5	Beach at Duero	99	89	40	14	5	1	0.5	------	2.68	32	240	299	214	301
6	Beach sand	100	100	99	94	85	35	18	2	2.73	43	257	319	151	192
7	Do	99	97	79	44	18	2	0.5	------	2.67	39	257	319	183	259
	BULACAN.														
8	Pulilan River	61	32	21	17	9	2	1.2	------	2.72	28	------	------	------	------
9	Bocaue River	49	14	7	5	3	0.9	0.6	------	2.67	35	------	------	------	------
10	Santo Niño River	98	89	63	46	15	5	4	------	2.70	37	------	------	------	------
11	Not known	99	92	67	47	16	2	0.5	------	------	------	------	------	------	------
12	Maasim	98	85	55	44	25	6	3	------	2.63	45	246	279	183	230
13	San Miguel	99	82	36	20	7	3	4	------	2.53	39	260	314	146	238
14	Santa Maria River	85	60	37	23	12	3	1	0.5	2.68	32	310	374	244	360
	BATAAN.														
15	Mariveles Beach, No. 0	100	99	99	89	76	36	10	------	2.60	47	308	366	162	225
16	Mariveles Beach, No. 1	------	------	------	------	------	------	------	------	2.62	45	308	366	128	194
17	Mariveles Beach, No. 2	------	------	------	------	------	------	------	------	2.74	42	308	366	188	242

	CAPIZ.														
18	Junction of Lauan and Capiz Rivers	97	91	72	63	40	4	1		2.63	41				
19	Jaro River, Jaro, Iloilo	91	74	52	43	26	8	5		2.64	33				
20	Panay River, Dao	71	42	23	18	10	4	1		2.63	32				
21	Bar at junction of Lauan and Capiz Rivers	98	91	78	69	68	8	4		2.64	39	342	428	191	279
	CAVITE.														
22	Rio Grande	62	31	18	10	6	2	1	0.5	2.41	44	257	354	266	314
23	Imus River	71	30	9	4	2	0.5	0.0	0.0	2.37	50	257	354	244	281
24	Rio Grande	65	28	13	6	4	2	1	0.5	2.33	34	261	321	240	287
	CEBU.														
25	Mananga River	79	48	25	18	11	5	3		2.67		307	351	319	416
26	Danao River											261	333	172	244
27	Unknown	100	99	89	80	62	11	2		2.70	44	250	342	175	275
28	Stream bed, kilometer 115.8 on Barili-South Road	94	65	16	8	3	2	2		2.63		219	325	188	249
	COTABATO.														
29	Linuac Beach, Cotabato	98	93	75	60	30	5	2		2.64	36				
30	Do	95	89	80	53	24	4	3	0.5	2.71	39	281	323	247	342
	ILOCOS NORTE.														
31	Laoag	96	85	58	43	24	10	5			37				
	ILOCOS SUR.														
32	Unknown	100	99	94	90	54	11	6		2.72	42				
	ILOILO.														
33	Unknown	96	89	75	66	35	7	1		2.61	41	265	341	231	325
34	Unknown, No. 2	100	96	89		75		1				265	341	217	310
35	Unknown, No. 3	88	66	38	9		1	0.4		2.58	39	265	341	253	358
36	La Paz	97	84	70	57	30	7	3		2.62		343	359	260	310
	JOLO.														
37	Jolo Beach	100	97	78	60	28	4	2		2.20	42	281	343	160	217
	LAGUNA.														
38	Barrio of Bayog, Los Baños	99	69	18	10	3	0.4					[a]169	[a]219	141	192
39	Barrio of Mayondon, Los Baños	99	79	30	15	6	2	0.6				[a]169	[a]219	134	182
40	Pagsanjan	74	27	7	3	2	1	0		2.62	30	213	325	171	283

[a] United States Army crushed quartz sand used in making briquettes.

TABLE 2.—*Physical tests of Philippine sands*—Continued.

Tracing No.	Province or origin of sand.	Percentage by weight of sand passing through sieve No.—								Specific gravity.	Voids.	Tensile strength in pounds per square inch of 1:3 mortar briquettes.			
												Ottawa sand.		Sand submitted for test.	
		10.	20.	30.	40.	50.	80.	100.	200.			7 days.	28 days.	7 days.	28 days.
	LEYTE.										*P. ct.*				
41	Tigbao River	79	38	10	5	3	1	-----	-----	2.74	36	-----	-----	-----	-----
42	Tabontabon	87	74	63	57	52	23	15	-----	2.72	-----	327	436	231	340
	MANILA.														
43	Mariquina River	66	27	10	6	3	0.2	-----	-----	2.68	31	240	285	290	347
44	Beach	98	96	95	88	73	17	9	5	2.73	45	223	283	97	150
45	Pasig River	95	76	33	24	9	2	1	-----	-----	-----	-----	-----	-----	-----
	MISAMIS.														
46	Cagayan River	98	87	49	35	20	5	2	1	2.63	42	-----	-----	-----	-----
47	Do	99	91	55	36	14	5	3	1	2.71	44	-----	-----	-----	-----
48	Do	44	10	6	4	3	1	0	-----	2.70	33	335	458	394	589
49	Mouth of Cagayan River	98	78	40	23	9	2	0	-----	2.79	38	-----	-----	-----	-----
50	Beach at mouth of Cagayan River	98	77	50	35	20	5	2	-----	2.63	42	-----	-----	-----	-----
	OCCIDENTAL NEGROS.														
51	Binalbagan River	97	82	46	26	10	2	1	-----	2.65	40	227	278	190	253
	ORIENTAL NEGROS.														
52	Bais River	81	53	26	19	12	2	1	-----	2.61	40	316	402	197	312
	PALAWAN.														
53	Beach at Coron	87	66	48	35	23	5	3	1	2.56	40	265	335	216	309
	PAMPANGA.														
54	Back of Camp Stotsenberg	88	68	46	34	25	12	7	-----	-----	-----	[a]169	[a]219	131	164

	PANGASINAN.														
55	Not given[a]	81	56	35	23	15	6	4	2	2.76	36	237	319	340	465
56	Limestone screenings crushed and graded at the Bureau of Science	45	28	23	18	15	9	5	2	2.58	40	237	319	408	490
	RIZAL.														
57	Mariquina River	85	74	36	33	17	2	1	-	-	39	367	351	335	428
	SAMAR.														
58	Beach	100	95	73	55	11	0.2	-	-	2.58	42	231	355	140	226
59	Do	100	100	99	97	96	85	52	-	2.59	45	231	355	40	181
60	Do	92	42	1	0.5	-	-	-	-	-	-	309	340	328	367
	SURIGAO.														
61	Surigao River	97	96	83	65	23	7	3	1	2.63	42	259	363	150	226
62	Wharf site	98	85	53	34	13	3	2	1	2.69	41	314	386	217	299
	TARLAC.														
63	Santiago River	59	26	15	8	5	2	1	-	2.71	37	257	354	290	382
	TAYABAS.														
64	Pit 1, Sariaya-Muntig River	77	46	28	17	11	4	3	2	2.67	32	280	375	303	417
	ZAMBALES.														
65	Anunang River	-	-	-	-	-	-	-	-	-	-	288	386	288	403
66	Mouth of Anunang River	-	-	-	-	-	-	-	-	-	-	288	386	181	287
67	Sitio of Galagala, 3.5 kilometers from bridge site	97	68	34	25	12	2	1	-	2.79	32	263	309	255	380
68	Mouth of Lucan River, 400 meters from bridge site	98	75	47	38	20	3	0.5	-	2.67	34	263	309	357	430
69	Lauis River, 1 kilometer from bridge site	88	65	25	16	7	1	0.5	-	2.75	32	299	380	290	436
70	Mouth of Yamot River, 2 kilometers from bridge site	99	96	49	23	6	2	-	-	2.72	33	322	366	215	274
71	Beach south of Kiling	99	94	50	31	8	2	-	-	2.84	37	-	-	-	-
72	Kauayan-Kiling River	83	45	15	10	5	2	0.5	-	2.63	36	-	-	-	-
	ZAMBOANGA.														
73	Beach	86	60	41	30	15	5	1	-	2.66	29	273	334	243	358
74	River	88	63	38	23	10	3	2	2	2.61	46	270	334	209	298

[a] United States Army crushed quartz sand used in making briquettes.

TABLE 2.—*Physical tests of Philippine sands*—Continued.

Tracing No.	Province or origin of sand.	Compressive strength in pounds per square inch of 1:3 mortar cylinders.				Date of test.	Remarks.
		Ottawa sand.		Sand submitted for test.			
		7 days.	28 days.	7 days.	28 days.		
	ALBAY.						
1	Unknown	1,864	2,610	1,460	2,010	Jan. 7, 1915	Basaltic and andesitic sand proposed for use on bridges and culverts on Guinobatan-Jovellar Road.
2	Quinale River	1,611	2,472	1,375	2,600	Jan. 25, 1915	
3	Guinobatan River	1,942	2,490	1,267	2,400	Feb., 1915	Intended for use on Bridge No. 8.1, Guinobatan-Jovellar Road.
4	Unknown	1,925	2,737	1,550	2,537	July, 1915	Intended for use on Quinale Bridge.
	BOHOL.						
5	Beach at Duero	2,012	3,045	1,148	1,919	Feb., 1918	Very clean sand, composed of smooth, rounded, granitic grains, 90 per cent; quartz, 5 per cent; and shell fragments, hornblende, and mica, 5 per cent.
6	Beach sand	1,092	2,109	408	580	Oct., 1917	Very fine, clean beach sand, containing about 90 per cent of rounded quartz grains.
7	Do	1,092	2,109	651	1,204	do	Fine beach sand, composed of 90 per cent of rounded shell and coral fragments.
	BULACAN.						
8	Pulilan River					Oct., 1915	Sand contains quartz and a high percentage of basalt.
9	Bocaue River					do	Coarse river sand, containing quartz, basalt, and some magnetite.
10	Santo Niño River					do	Fine sand, derived from igneous rocks, and contains quartz, basalt, magnetite, and shell fragments.
11	Not known					Jan. 17, 1912	Used in Santo Niño Bridge and in making concrete cubes at Bureau of Science.
12	Maasim					Dec. 29, 1912	Composed of quartz, fragments of andesite, ilmenite, hematite, and magnetite.

13	San Miguel					Apr. 23, 1913	Used in Bolo River Bridge.
14	Santa Maria River	1,474	2,385	1,130	2,310	Nov. 22, 1917	Medium coarse sand, derived from vesicular basalt and used in constructing Santa Maria Bridge.
	BATAAN.						
15	Mariveles Beach, No. 0					Nov. 27, 1909	In connection with proposed barrack building at Mariveles Quarantine Station, but rejected on account of extreme fineness; mortar tests very low.
16	Mariveles Beach, No. 1					Jan., 1916	Clean calcareous sand, composed of about 72 per cent shell débris; said to have good granulometric composition. Proposed for barrack building at Mariveles Quarantine Station.
17	Mariveles Beach, No. 2					do	Composed of about 70 per cent shell débris.
	CAPIZ.						
18	Junction of Lauan and Capiz Rivers		2,955		1,375	do	Fine sand, containing quartz, magnetite, olivine, basalt, and shell fragments. Soft grains of weathered rock present; proposed for constructing Libas Bridge.
19	Jaro River, Jaro, Iloilo		3,231		2,597	do	Proposed for use on Balucuan and Libas Bridges, in Dao and Capiz, respectively.
20	Panay River, Dao		2,824		2,723	do	Fairly coarse, graded sand for use in Balucuan Bridge.
21	Bar at junction of Lauan and Capiz Rivers.					Dec., 1915	Contains quartz, hornblende tuff, basalt, and shell fragments; used in constructing Ivisan School, Ivisan.
	CAVITE.						
22	Rio Grande	783	1,878	1,584	2,804	Dec. 20, 1916	Coarse sand, composed of soft fragments of volcanic rock; no quartz grains present.
23	Imus River	783	1,878	1,534	1,998	do	Coarse sand, containing no quartz grains; appreciable quantities of light, porous, scorialike pebbles present.
24	Rio Grande	657	1,824	602	1,113	Dec., 1916	Composed mostly of ferro-magnesian minerals; very little quartz present.
	CEBU.						
25	Mananga River					Sept. 30, 1912	
26	Danao River						
27	Unknown						Composed of hornblende, olivine, and small quantities of quartz, sand proposed for Cebu Quarantine Station.
28	Stream bed, kilometer 115.8 on Barili-South Road.					May 8, 1913	

TABLE 2.—*Physical tests of Philippine sands*—Continued.

Tracing No.	Province or origin of sand.	Compressive strength in pounds per square inch of 1:3 mortar cylinders.				Date of test.	Remarks.
		Ottawa sand.		Sand submitted for test.			
		7 days.	28 days.	7 days.	28 days.		
	COTABATO.						
29	Linuac Beach, Cotabato	3,201	4,637	2,559	4,327	Nov. 26, 1915	Used in constructing Cotabato Hospital; consists principally of quartz, with ferro-magnesian minerals and shell fragments.
30	Do	1,091	1,393	1,056	1,519	May, 1917	Contains about 50 per cent quartz; used in constructing Cotabato River wall drain pipe, Cotabato Hospital.
	ILOCOS NORTE.						
31	Laoag						Composed principally of quartz, with fragments of magnetite and andesite; used for replacing the destroyed spillway of Gilbert Bridge.
	ILOCOS SUR.						
32	Unknown					Mar. 17, 1915	Quartz sand used in the construction of Singson Waterworks.
	ILOILO.						
33	Unknown						Proposed for constructing Molo Bridge, but rejected.
34	Unknown, No. 2						Do.
35	Unknown, No. 3					Jan. 16, 1911	Used in constructing Molo Bridge.
36	La Paz					June 18, 1911	Grains hard and clean.
	JOLO.						
37	Jolo Beach	1,279	2,030	774	938	April 8, 1914	Derived from coral and shells.
	LAGUNA.						
38	Barrio of Bayog, Los Baños						
39	Barrio of Mayondon, Los Baños						
40	Pagsanjan	842	1,246	919	1,416	Dec., 1918	Clean, coarse, angular basalt sand, containing practically no quartz; used in constructing the Pagsanjan Waterworks.

	LEYTE.						
41	Tigbao River		5,004		3,946	Dec., 1915	Proposed for constructing Tacloban Port Works.
42	Tabontabon	3,316	3,612	2,861	3,694	do	Used in constructing Tabontabon School.
	MANILA.						
43	Mariquina River	796	1,360	1,130	1,565	Aug. 10, 1915	Used in constructing Masonic Temple, Manila.
44	Beach					July, 1917	Used by cadastral survey, Bureau of Lands, for making monuments, but discontinued on account of unsatisfactory results.
45	Pasig River						
	MISAMIS.						
46	Cagayan River					March, 1916	Proposed for constructing Cagayan Wharf.
47	Do					do	Do.
48	Do	1,508	2,827	2,608	5,508	Sept., 1916	Clean, very coarse sand, composed principally of hard, rounded, basaltic pebbles; very little quartz present; proposed for Cagayan Central School.
49	Mouth of Cagayan River					April, 1916	Contains appreciable quantities of magnetite and olivine, and very little quartz; proposed for Macabalan Wharf.
50	Beach at mouth of Cagayan River					Mar. 6, 1916	Rock pebble sand, containing small quantities of quartz; proposed for constructing Cagayan Wharf.
	OCCIDENTAL NEGROS.						
51	Binalbagan River	1,300	1,698	1,077	1,627	Oct., 1916	Proposed for constructing Binalbagan Bridge, Isabela.
	ORIENTAL NEGROS.						
52	Bais River	1,704	2,425	779	2,199	Mar., 1916	Contains considerable coralline limestone grains; proposed for Bais River Bridge.
	PALAWAN.						
53	Beach at Coron	1,613	2,618	854	1,149	Mar., 1917	Angular, iron-stained quartz sand, proposed for construction of Coron Wharf.
	PAMPANGA.						
54	Back of Camp Stotsenberg						

TABLE 2.—*Physical tests of Philippine sands*—Continued.

Tracing No.	Province or origin of sand.	Compressive strength in pounds per square inch of 1:3 mortar cylinders. Ottawa sand. 7 days.	Ottawa sand. 28 days.	Sand submitted for test. 7 days.	Sand submitted for test. 28 days.	Date of test.	Remarks.
	PANGASINAN.						
55	Not given	1,624	2,463	1,896	2,042	July, 1917	Diorite pebble sand containing less than 1 per cent quartz; shell fragments and magnetite grains present; proposed for constructing Lingayen Provincial Building.
56	Limestone screenings crushed and graded at the Bureau of Science.	1,624	2,463	2,186	2,913	do	Pangasinan limestone, crushed and graded (100 per cent through 0.25-inch mesh opening) at Bureau of Science to yield a mortar of high strength. Proposed for Provincial Building, Lingayen.
	RIZAL.						
57	Mariquina River	2,030	2,654	1,662	2,164	Feb., 1916	Used in constructing Angono Bridge, Binangonan, Rizal.
	SAMAR.						
58	Beach	1,252	1,983	829	935	1914	Fine beach sand, containing much shell débris.
59	Do	1,252	1,983	241	829	do	Very fine beach sand, containing much calcareous matter.
60	Do	1,973	2,980	1,833	2,948	Nov. 24, 1914	In connection with construction of Ilo, Sorsogon, and Bachow Bridges.
	SURIGAO.						
61	Surigao River	1,116	1,956	598	894	Nov., 1915	Quartz sand with a small percentage of limestone. Proposed for constructing Bilang-bilang Wharf, Surigao.
62	Wharf site	1,143	2,078	876	1,534	Oct., 1915	Quartz sand with admixture of basalt and andesite grains. Proposed for constructing Bilang-bilang Wharf.

	TARLAC.						
63	Santiago River	783	1,878	2,485	2,995	Nov., 1916	Contains less than 5 per cent of quartz; composed principally of clear, glassy grains of plagioclase feldspar. Proposed for use in constructing bridge 5.5, Capas-Concepcion Road.
	TAYABAS.						
64	Pit 1, Sariaya-Muntig River	2,005	2,323	2,196	3,685	Nov., 1917	Angular pebble sand containing no quartz and derived principally from basalt. Proposed for constructing bridge No. 23.6, Lucena-Tiaong Road over Quiapo River.
	ZAMBALES.						
65	Anunang River	2,303	2,312	1,964	2,069	Mar. 20, 1916	Proposed for constructing Anunang River Bridge, Cabangan, Zambales.
66	Mouth of Anunang River	2,303	2,312	1,689	2,351		
67	Sitio of Galagala, 3.5 kilometers from bridge site.	1,176	1,679	923	1,234	Sept., 1916	Very clean, hard-grained sand, proposed for constructing Candelaria School, Candelaria, Zambales.
68	Mouth of Lucan River, 400 meters from bridge site.	1,176	1,679	1,279	2,115	do	Very clean sand; proposed for constructing Lucapon Bridge, Alhambra, Zambales.
69	Lauis River, 1 kilometer from bridge site.	1,593	2,679	1,700	3,127	July, 1916	Proposed for Yamot Bridge.
70	Mouth of Yamot River, 2 kilometers from bridge site.	1,593	2,679	1,325	1,959	do	Do.
71	Beach south of Kiling					Jan., 1916	Composed of quartz grains; proposed for bridges, Iba-Subic Road.
72	Kauayan-Kiling River		2,918		2,870	do	Proposed for bridges, Iba-Subic Road.
	ZAMBOANGA.						
73	Beach	912	1,450	738	1,298	Feb., 1918	Very clean sand, containing about 20 per cent coral and shell fragments; 4 per cent milky quartz; and 76 per cent rock pebbles; proposed for Zamboanga Normal School.
74	River	912	1,450	317	661	do	Fairly clean sand containing less than 5 per cent quartz, and principally composed of volcanic and metamorphic rock pebbles, about 10 per cent of which are in an advanced state of decomposition.

TABLE 3.—*Granulometric analyses of Philippine gravels.*

Province or origin of gravel.	Percentage by weight of gravel passing through circular opening having a diameter of—						Date of test.	Remarks.
	2.25 inches.	1.50 inches.	1 inch.	0.67 inch.	0.45 inch.	0.30 inch.		
ALBAY.								
Unknown		66	46	23	6	1	Jan. 7, 1915	Vesicular andesite, proposed for bridges and culverts on Guinobatan-Jovellar Road.
BATAAN.								
Mariveles beach, No. 2	99		71	30	10			Specific gravity, 2.56; voids, 46 per cent; gravel soft and highly weathered.
Mariveles beach, No. 3		100	98	93	79	60		Contains 33 per cent sand; specific gravity, 2.47; voids, 46 per cent.
Mariveles beach, No. 4	80	38	32	6				Three per cent retained on 3-inch circular opening; only the portion passing 1.5-inch circular opening used in concrete.
Sisiman crushed andesite from Mariveles, No. 5.	83	18	3					Ninety-eight per cent passed through 3-inch circular opening; only the portion passing 1.5-inch circular opening used for concrete; specific gravity 2.62; rock hard and tough.
BULACAN.								
Pulilan River	100	83	41	18	0.2	0.0	Oct., 1915	Altered basalt impregnated with pyrites.
Bocaue River	100	77	50	31	26	0.4	do	Altered basalt.
Quiñgua River		100	77	51	22	8		One per cent through 0.20-inch circular opening.
Bocaue River		100	97	80	42	16		Do.
San Miguel		100	96	89	67	43	May, 1913	Contains 3 per cent sand; proposed for Bolo River Bridge.
Do		100	86	67	36	13	do	Proposed for Bolo River Bridge.
Sibul		100	71	57	37	22		Contains 11 per cent sand; proposed for Bolo River Bridge.
Santa Maria River		83	53	27	5	1		Soft, highly weathered gravel, derived from volcanic rock; used in Santa Maria Bridge.

CAVITE.								
Imus River		100	90	78	64	46		Sand content approximately 27 per cent; gravel contains basalt, andesite tuff, and shell fragments; specific gravity, 2.35; voids, 37.3 per cent; for use in constructing Aguinaldo School, Kawit.
Rio Grande	79	64	51	40	24	11		Contains about 10 per cent of sand; clean, hard gravel; specific gravity, 2.44; voids, 35.4 per cent.
Imus River	100	73	70	63	51	42		Composed largely of vesicular basalt; specific gravity, 2.10; voids, 45.9 per cent; contains about 30 per cent sand.
Rio Grande	75	68	57	45	30	20		Contains about 10 per cent sand; specific gravity, 2.60; voids, 39 per cent; soft gravel.
Do		100	87	70	46	34		Contains volcanic ejecta, basalt, and scoria; contains about 25 per cent sand; specific gravity, 2.40; voids 25.4 per cent.
CEBU.								
Mananga River		100	86	55	15	3		Specific gravity, 2.63.
Unknown		100	76	22	1	0.5		Composed of andesite pebbles, specific gravity, 2.64; voids, 42 per cent. Proposed for Cebu Quarantine Station.
ILOCOS NORTE.								
Laoag	100	93	82	65	18	9		Andesite pebbles; used in the reconstruction of the destroyed spillway of Gilbert Bridge.
ILOCOS SUR.								
Unknown	100	80	69	45	10	2	Mar. 17, 1915	Used in constructing Singson Waterworks, Vigan.
JOLO.								
Jolo beach		100	96	85	50	20	Apr. 8, 1914	Composed of coral fragments, and contains 17 per cent sand; specific gravity, 2.39; voids, 56.3 per cent.
LAGUNA.								
Crushed rock from upper ledge of quarry at Los Baños.		100	23	6	3	2		Hard, durable basalt.
MANILA.								
Mariquina River	100	86	68	56	30	8	Aug. 10, 1915	
MISAMIS.								
Beach			100	33	3	0	Mar., 1916	Proposed for Cagayan Wharf.
Cagayan River		100	98	89	63	40	do	Proposed for Cagayan Wharf; contains about 25 per cent sand.
Do	100	83	34	20	0		Sept., 1916	Proposed for Cagayan Central School.

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TABLE 3.—*Granulometric analyses of Philippine gravels*—Continued.

Province or origin of gravel.	Percentage by weight of gravel passing through circular opening having a diameter of—						Date of test.	Remarks.
	2.25 inches.	1.50 inches.	1 inch.	0.67 inch.	0.45 inch.	0.30 inch.		
ORIENTAL NEGROS.								
Bais River	100	59	48	27	8	2	Mar., 1916	Soft gravel, proposed for constructing Bais River Bridge.
PAMPANGA.								
Crushed run surface rock from Camp Stotsenberg.		100	38	23	11	7		Soft, hornblende andesite.
Crushed float rock from Banaban River.		100	21	7	1			Hard basalt, having pronounced cleavage planes.
PANGASINAN.								
Unknown	100	91	87	69	29	5		Proposed for Provincial Building, Lingayen; composed principally of diorite.
RIZAL.								
Añgono River	83	83	56	45	29	17		Contains about 5 per cent sand; proposed for constructing Añgono Bridge, Binangonan, Rizal.
ZAMBALES.								
Beach gravel from Galagala, 3.5 kilometers from bridge site.	100	94	18				Sept., 1916	Hard, clean gravel, containing appreciable quantities of quartz pebbles. Proposed for Candelaria School.
Lauis River, 4 kilometers from bridge site.	81	64	7	0.3			June, 1916	Coarse, clean, hard gravel; proposed for Yamot Bridge.
Cabangan River	100	49	3	0.4			Jan., 1916	Composed of hard, volcanic, metamorphic rock; proposed for bridges on Iba-Subic Road.

Specific gravity.—Sixty-four grams of the dried sand were introduced into a Le Chatelier flask filled to the zero mark with 95 per cent alcohol. The rise of the meniscus on the graduated neck represents the volume displaced by the grains of sand. Dividing the mass of the sample used by the displacement in cubic centimeters indicated on the neck of the flask quickly and accurately gives the specific gravity of the sand.

For determining the specific gravity of the coarse aggregate about 1,000 grams of the dried gravel were accurately weighed, and then allowed to rest under water for twenty-four hours in order to fill the pores. After the aggregate was saturated with water, it was quickly dried with a cloth, then with a blotter, and the displacement of the gravel noted in a large graduated cylinder containing a measured quantity of water. The specific gravity was calculated from the well-known formula:

$$\text{Specific gravity} = \frac{\text{Mass}}{\text{Volume}}$$

Granulometric analysis.—In determining the granulometric analysis of sand, 200 grams of a representative sample were successively shaken on a series of sieves ranging from 10 to 200 meshes to the linear inch and the residue on each sieve was weighed. The sieves are 8 inches in diameter and fitted with double-crimped, brass, wire cloth having square mesh openings. In Table 4 are recorded the actual mesh and wire sizes, obtained by examining the sieves under a microscope fitted with an ocular micrometer. The granulometric results obtained during the period 1908 to 1914 were secured by hand sieving; results after 1914 were gotten by using an electrically driven sieving apparatus commercially known as The Per Se Testing Sieve Agitator manufactured by Howard and Morse, of Brooklyn, New York.

TABLE 4.—*Mesh, space, and wire sizes of sieves used in performing granulometric analyses of Philippine sands.*

Meshes per linear inch.	Width of clear opening from one wire to another.		Diameter of wire.	
	in.	*mm.*	*in.*	*mm.*
10	0.0734	1.87	0.0266	0.675
20	0.0323	0.820	0.0177	0.450
30	0.0203	0.517	0.0130	0.330
40	0.0144	0.365	0.0106	0.270
50	0.0111	0.283	0.0089	0.225
80	0.0066	0.168	0.0059	0.150
100	0.0053	0.134	0.0047	0.120
200	0.0026	0.067	0.0024	0.060

For the granulometric test of gravel and crushed stone, a set of sieves was used having circular openings ranging in diameter from 2.25 inches down to 0.30 inch, namely 2.25, 1.50, 1.00, 0.67, 0.45, and 0.30. Instead of wire cloth, these sieves consisted of sheet iron punched with round holes, which was soldered to a circular frame 12 inches in diameter and 3 inches deep.

A 2,000-gram sample of the dry gravel was placed on the sieve with the largest opening and shaken by hand until no more of the material passed through. The material coming through this screen was placed on the sieve next smaller in hole opening and the sieving performed as before, and the process continued with the other sieves in the series. The portions of aggregate remaining on each of the screens were weighed and recorded.

Tensile and compressive strength tests.—The sands and screenings were tested for tensile strength in the proportions by weight of one part cement to three parts sand. Three-gang standard briquette molds were used for molding the test specimens. The briquettes were made in accordance with the directions prescribed in the United States Government specification for Portland cement.[3]

Specimens for compression were made in the proportions by weight of one part cement to three parts sand, but in several instances the smallness of the sample precluded such a test. The compression specimens were cylindrical, with a diameter of 3.568 inches and a height of 7.136 inches. The cylinder-shaped molds used in forming these test pieces are constructed of cast iron and are split vertically into halves for facility in removing the specimens. During the molding operation, the two halves of the mold are held together by a cast-iron ring that encircles the body of the mold with a taper fit. The diameter was made 3.568 inches so that the area of the bearing faces would be exactly 10 square inches, as this greatly facilitates the calculation of the strength per square inch. The height was made twice the least lateral diameter in order to secure the correct shearing angle during rupture. For the purpose of comparison briquettes and cylinders were molded of mortar composed of one part cement and three parts standard Ottawa sand, by weight. Both the tension and the compression test mortar specimens, unless otherwise noted, were stored for the first twenty-four hours in a moist-air cabinet; at the end of this period the test pieces were removed from the molds and stored up to the time of rupture in fresh running water maintained at an average temperature of 28° C.

[3] United States Government Specification for Portland Cement, Circular Bur. Standards 33 (May 1, 1912, and January 18, 1917).

In Table 5 are recorded typical results of physical tests of eight brands of Portland cement that have been used in concrete construction in the Philippine Islands. These tests were made in the materials testing laboratory of the Bureau of Science in accordance with the United States Government specification for Portland cement.[4] The requirements of the older specification were in force in the Philippine Islands until May 24, 1918, and are abstracted here for convenience in studying the results given in Table 5.

2. In the finished cement, the following limits shall not be exceeded:

	Per cent.
Loss on ignition for 15 minutes	4.00
Insoluble residue	1.00
Sulphuric anhydride (SO_3)	1.75
Magnesia (MgO)	4.00

SPECIFIC GRAVITY

3. The specific gravity of the cement shall be not less than 3.10. Should the cement as received fall below this requirement, a second test may be made upon a sample heated for 30 minutes at a very dull red heat.

FINENESS

4. Ninety-two per cent of the cement, by weight, shall pass through the No. 100 sieve, and 75 per cent shall pass through the No. 200 sieve.

SOUNDNESS

5. Pats of neat cement prepared and treated as hereinafter prescribed shall remain firm and hard and show no sign of distortion, checking, cracking, or disintegrating. If the cement fails to meet the prescribed steaming test, the cement may be rejected or the steaming test repeated after seven or more days at the option of the engineer.

TIME OF SETTING

6. The cement shall not acquire its initial set in less than 45 minutes and must have acquired its final set within 10 hours.

TENSILE STRENGTH

7. Briquettes made of neat cement, after being kept in moist air for 24 hours and the rest of the time in water, shall develop tensile strength per square inch as follows:

	Pounds.
After 7 days	500
After 28 days	600

8. Briquettes made up of 1 part cement and 3 parts of standard Ottawa sand, by weight, shall develop tensile strength per square inch as follows:

	Pounds.
After 7 days	200
After 28 days	275

[4] United States Government Specification for Portland Cement, Circular Bur. Standards 33 (May 1, 1912, and January 18, 1917).

The foregoing specification has been superseded by that published in the third edition of Circular 33, issued January 18, 1917. The latter United States Government specification for the testing of Portland cement has been in force in the Philippine Islands since May 24, 1918, and is effective at the present time. For the purpose of comparison, the new requirements are here given.

CHEMICAL LIMITS

2. The following limits shall not be exceeded:

	Per cent.
Loss on ignition	4.00
Insoluble residue	0.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

SPECIFIC GRAVITY

3. The specific gravity of cement shall be not less than 3.10 (3.07 for White Portland cement). Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

FINENESS

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

SOUNDNESS

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

TIME OF SETTING

6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

TENSILE STRENGTH

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test.	Storage of briquettes.	Tensile strength, pounds per square inch.
Days.		
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

The foregoing specification has been superseded by that published in the third edition of Circular 33, issued January 18, 1917. The latter United States Government specification for the testing of Portland cement has been in force in the Philippine Islands since May 24, 1918, and is effective at the present time. For the purpose of comparison, the new requirements are here given.

CHEMICAL LIMITS

2. The following limits shall not be exceeded:

	Per cent.
Loss on ignition	4.00
Insoluble residue	0.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

SPECIFIC GRAVITY

3. The specific gravity of cement shall be not less than 3.10 (3.07 for White Portland cement). Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

FINENESS

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

SOUNDNESS

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

TIME OF SETTING

6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

TENSILE STRENGTH

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test.	Storage of briquettes.	Tensile strength, pounds per square inch.
Days.		
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

TABLE 5.—*Typical results of physical tests conducted upon Portland cements used in the Philippines.*

Tracing No.	Brand.	Manufactured in—	Tested.	Results averaged.	Fineness, percentage through— 200 mesh.	Fineness, percentage through— 100 mesh.	Specific gravity.	Soundness. 5 hours in steam.	Soundness. 28 days in water.	Setting time. Initial.	Setting time. Final.	Tensile strength, pounds per square inch. Neat. 7 days.	Neat. 28 days.	1:3 Ottawa mortar. 7 days.	1:3 Ottawa mortar. 28 days.	Remarks.
										h. m.	*h. m.*					
1	Asano	Japan	Nov. 10, 1916	10	86	97	3.11	O. K.	O. K.	4 12	6 25	597	648	252	362	All results within specifications.
2	Do	do	Apr. 22, 1918	100	81	97	3.11	O. K.	O. K.	4 39	7 09	[a] 456	[b] 550	[c] 197	[d] 308	
3	Alsen	Germany	Sept. 12, 1912	100	82	98	3.08	O. K.	O. K.	1 56	4 26	[e] 587	[f] 617	[g] 294	364	
4	Do	do	July 3, 1911	20	77	96	3.08	O. K.	O. K.	1 38	4 41	[h] 501	[i] 606	263	315	
5	Caballo	China	Oct. 8, 1917	20	78	97	3.11	O. K.	O. K.	3 36	5 13	594	636	289	356	Do.
6	Do	do	Mar. 2, 1918	100	82	96	3.11	O. K.	O. K.	3 13	6 29	[j] 547	[k] 606	236	[l] 303	
7	Culebra	Japan	Dec. 15, 1915	20	80	98	3.11	O. K.	O. K.	5 08	7 52	609	737	277	369	Do.
8	Do	do	Oct. 23, 1919	37	71	------	3.12	O. K.	------	3 34	6 40	------	------	[m] 179	[n] 261	
9	Green Island	China	Mar. 11, 1911	60	78	97	3.10	O. K.	O. K.	[o] 1 26	3 38	598	[p] 659	276	336	
10	Do	do	Apr. 18, 1911	10	77	97	3.12	O. K.	O. K.	3 02	5 33	654	719	[q] 226	[r] 297	
11	Haiphong	Indo-China	Feb. 25, 1916	12	84	98	3.09	O. K.	O. K.	4 12	7 41	565	654	237	308	Do.
12	Do	do	June 17, 1910	35	83	98	3.09	O. K.	O. K.	1 51	5 04	[s] 511	[t] 619	[u] 220	[v] 285	
13	Onada	Japan	Jan. 18, 1916	25	89	99	3.14	O. K.	O. K.	4 29	7 45	555	659	283	374	Do.
14	Do	do	Jan. 25, 1916	25	88	98	3.14	O. K.	O. K.	5 35	7 25	554	[w] 650	260	330	
15	Rizal	Philippine Is.	Oct. 4, 1916	10	80	98	3.12	O. K.	O. K.	3 34	5 34	566	631	237	324	Do.
16	Do	do	May 15, 1916	40	79	94	3.14	(x)	O. K.	2 30	4 39	[y] 547	[z] 644	[aa] 160	[bb] 256	

[a] 92 samples failed.
[b] 97 samples failed.
[c] 53 samples failed.
[d] 39 samples failed.
[e] 1 sample failed.
[f] 1 sample failed.
[g] 78 samples failed.
[h] 10 samples failed.
[i] 8 samples failed.
[j] 10 samples failed.
[k] 35 samples failed.
[l] 9 samples failed.
[m] 28 samples failed.
[n] 30 samples failed.
[o] 2 samples failed.
[p] 1 sample failed.
[q] 2 samples failed.
[r] 3 samples failed.
[s] 15 samples failed.
[t] 11 samples failed.
[u] 7 samples failed.
[v] 9 samples failed.
[w] 2 samples failed.
[x] 27 samples unsound.
[y] 4 samples failed.
[z] 2 samples failed.
[aa] 39 samples failed.
[bb] 33 samples failed.

In this laboratory it is customary to test one barrel of cement in every ten. Each sample of cement received by the Bureau of Science, so far as the Government is concerned at least, therefore represents ten barrels of cement. Only one sample in every ten is tested for fineness, one in every five for time of setting and for specific gravity, but every sample is tested for soundness and tensile strength. An incomplete chemical analysis is also made of every lot of cement received by the laboratory, a single composite sample being taken for this purpose. Table 6 gives the loss on ignition, insoluble residue, sulphuric anhydride, and magnesia of some cements used in the Philippine Islands.

TABLE 6.—*Incomplete chemical analyses of Portland cement used in the Philippine Islands.*

Brand.	Loss on ignition.	Insoluble residue.	Sulphuric anhydride.	Magnesia.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Asano	1.63	0.55	1.30	1.35
Caballo	2.10	0.25	1.17	2.12
Culebra	1.90	0.35	1.16	1.96
Green Island	1.85	0.44	1.25	1.95
Onada	1.46	0.41	1.50	1.79
Rizal	2.73	0.53	1.62	1.54

In Table 7 are recorded the number of samples of Portland cement tested at the materials testing laboratory since the inception of such work in 1907 at the Bureau of Science. Previous to that year the testing of Portland cement was scattered throughout the various government entities using it.

Mineralogical composition.—Some of the sands were examined under the magnifying glass for the purpose of making a rough approximation to their mineralogical composition. In order

TABLE 7.—*Number of samples of Portland cement tested at the Bureau of Science.*

Year.	Samples.	Year.	Samples.
1907	24	1914	6,817
1908	1,200	1915	6,716
1909	[a] 2,788	1916	15,790
1910	[a] 3,293	1917	5,687
1911	[a] 3,724	1918	4,999
1912	8,476	1919	6,888
1913	9,535		

[a] Figures include a small unknown number of soil, fertilizer, and sand samples.

to determine the mineralogical nature of the grains it was generally necessary to free them from adhering dust, dirt, or clay by washing with water. Representative pieces of the coarse aggregates (gravels and stone) were fractured by rapping them sharply with a geological hammer, and the clean broken surface was examined macroscopically.

TECHNIC OF CONCRETE TESTS

Method of mixing and molding.—All proportions used in this paper to indicate concrete mixtures are by volume. For proportioning the mixtures the weight of a cubic foot of cement was assumed to be 90 pounds. Both the sand and the gravel were measured dry, and compacted in the measuring boxes by gentle percussion. After having found the weight of a unit volume of the compacted aggregate it was more convenient to proportion the mix by using the weight of a unit volume of the materials. The aggregates required for a mixture were weighed instead of actually measured by volume, and the loss in time and the tediousness of compacting them were thus avoided. Likewise, it was more convenient and more accurate to weigh the cement for the various tests and then to calculate the volume, than actually to measure by volume the cement required. The sand and cement were then intimately mixed with a shovel on a concrete slab, after which the gravel was added and the whole thoroughly mixed in the dry state. In these laboratory tests the batches never weighed more than 30 kilograms, so that it was a comparatively easy matter to secure a homogeneous mixture. A crater was next made in the middle of the heap and water amounting to from 7 to 10 per cent (depending upon the granular sizes of the sand and gravel) of the total weight of the dry batch was added; fine aggregates always required more water than coarse ones. The consistency sought in these tests may be described as "quaking;" such a mixture is a fairly stiff one, which upon slight tamping yields water on the surface. The mass does not flow readily and has to be spaded and rammed vigorously to produce specimens free from honeycombing. The test pieces were made by tamping the concrete into the molds in layers about 1 inch thick; the mold was also subjected to a vibratory motion by rapping the outside with a wooden block. When the mold was full, the top surface of the specimen was smoothly finished with a trowel. Most of the laboratory specimens were 6-inch cubes; some concretes made of small-sized gravels were cast in the cylindrical molds already described under mortar tests. At the end of twenty-four hours the speci-

mens were taken out of the molds and stored either in the laboratory air or in the moist-air closet until the time of rupture.

With a few exceptions, the test specimens sent to the materials testing laboratory of the Bureau of Science were hand-mixed. From personal observation of the activities of concrete-mixing gangs in various parts of the Archipelago I am in a position to account for the exceptionally low and erratic results obtained from specimens made on the building site. Laboratory tests of many of the aggregates gave high and uniform results; however, the proportioning of the same aggregates and cement in the field in the Philippine Islands is, in general, a haphazard operation that results in an arbitrary mixture which bears little relationship to the concrete prescribed by the designer. In some instances both the cement and the aggregates are measured loosely, with the result that instead of using from 90 to 100 pounds to the cubic foot as packed in the barrel, the cement is used in volumes that weigh anywhere from 50 to 70 pounds to the cubic foot. By using this method one barrel of cement is made to go a long way, but the resultant concrete is very friable and gives extraordinarily low compressive strength. In other instances I have seen the sand and gravel measured in wheelbarrows—a certain number of loads of each to one barrel of cement—with the result that the actual ratio of cement to sand to gravel was unknown.

Irregularities also occur in the operation of mixing that cast light on the discordant results secured from a lot of specimens made from the same batch of concrete. The usual method employed in making concrete by hand in the Philippines is to mix the sand and cement dry until it is fairly homogeneous; in general this means that a barrel of cement is dumped on the sand and the pile shoveled through once to form a cone. Sometimes the cone thus formed is shoveled through once more. The workmen now form a crater in the center of the cone while a man plays an ordinary garden hose or pours pails of water into the depression thus formed. The amount of water added is determined by the mixers, who continue to call for water until the mortar has lost all of its stiffness and plasticity, and the shovel can be passed through the mass with a minimum amount of labor. No attempt is made to measure the water; it is used in such superabundance largely for the purpose of reducing to a minimum the work of mixing and placing. The mortar thus drenched with water is soupy, and more than once I have seen it flow over the edge of the wooden mixing

board. The mortar is now distributed on the gravel layer which has been spread on the mixing board to a depth that may range from 6 to 12 inches. Two or four men with shovels, stationed in pairs and facing each other, now proceed to mix the superimposed blanket of mortar with the underlying layer of gravel in such a manner that the mortar is incorporated with only that portion of gravel lying directly underneath it so that the mass as a whole is not thoroughly intermingled, but is mixed sectionwise. In other words the two-layered mound of mortar and gravel is shoveled directly into buckets or wheelbarrows used for conveying the concrete to the structure, after each shovelful has been subjected to an average of four turns. During this last mixing operation a man stands by with a hose or with pails of water to do the bidding of the men engaged in the mixing operation, who call for water as long as the mass offers decided resistance to the passage of the shovel on account of plasticity. They aim to get as wet a mix as possible in order to reduce their work to a minimum and to facilitate the placing of the concrete in the structure. The result is a soupy, nonuniform concrete, subject to segregation while being conveyed to its final resting place and while being placed. On account of the excessive amount of water added the concrete so mixed will have a low compressive strength, as tests have already shown.

The concrete specimens cast in the field lacked the careful workmanship shown by the cylinders and cubes molded in the laboratory. In some few cases the honeycombed texture of the concrete test pieces made on the building site showed evidence of lack of tamping and spading. Their chief fault, however, was the irregular manner in which the cylinder ends had been finished so that it was necessary to embed them in plaster of Paris before they could be subjected to the compression test. Careless packing accounted for injuries sustained by some test pieces during transport from the building site to the laboratory, as a result of which no tests were possible.

Data on the storage of concrete specimens fabricated in the field show considerable variation. On account of the distance between the building site and the laboratory and the irregularities of interisland communication, it was not always possible to receive the specimens in time to break them at the end of twenty-eight days. Results obtained from such belated test pieces lose some of their comparative value; but they have been included in this paper in order to convey some idea of the quality of

the concrete used in the particular structure concerned. Field specimens, referred to as stored in moist air, may be considered as having been sprinkled with water or as having been kept under moist sacking or buried in the ground.

METHOD OF TESTING

To insure uniform distribution of the load on the specimens made in the field it was found necessary to embed in plaster of Paris the rough ends bearing on the testing machine. The test pieces made in the laboratory were so smoothly finished that capping with plaster was unnecessary; but a piece of cardboard was interposed between the bearing surfaces and the table and crosshead of the machine.

In embedding the ends of a specimen, plaster was thinly spread on a piece of cardboard resting upon a surface plate and one end of the test piece pressed in by hand so that plaster oozed out on all sides. After the plaster had set, the specimen was turned upside down and the other end forced into a thin layer spread on a piece of cardboard resting on a spherical bearing block. This time the specimen was pressed into the plaster by the testing machine, care being taken not to exceed an average pressure of 30 pounds per square inch. After resting for at least twelve hours, the specimens were centered on a spherical bearing block that rests on the weighing table of the testing machine, and the test pieces together with the upper section of the spherical block were slowly rotated to insure uniform bearing, while the crosshead was brought down upon the specimen. The load was applied uniformly at the rate of about 0.5 millimeter per minute. After rupture, the specimen was removed from the machine, and the fragments examined to determine the nature of the failure. If only the mortar had failed, the test was reported as a "mortar failure;" whereas, if considerable gravel or stone had been sheared or fractured in addition, the specimen was reported as a "gravel and mortar failure."

DISCUSSION OF RESULTS

In Table 8 are recorded data obtained in testing 1,677 specimens of concrete. Most of these results were gotten from test pieces made in the field throughout the Archipelago; the rest were from specimens made in the materials testing laboratory of the Bureau of Science of aggregates sent by district engineers in charge of provincial building projects.

ALBAY

Examination of the data on compressive strength of concrete specimens listed under Albay, in Table 8, shows that the field

tests are fair. When classified into series and averaged the results are consistent in that the mixtures poorest in cement average weakest, and those richest in cement average strongest. Disregarding the slight differences in age of the various field specimens, it will be seen that the 1 : 3 : 6 mixtures average 607 pounds per square inch; the 1 : 2 : 5 mixtures, 923; and the 1 : 2 : 4 mixtures, 1,068. The corresponding results obtained from laboratory-made specimens average about twice as high; thus the results given by the 1 : 2 : 4 concrete made at the Bureau of Science average 2,578 pounds per square inch, and a single laboratory-made specimen of 1 : 3 : 6 concrete has a compressive strength of 1,046 pounds per square inch; these results are 2.5 and 1.7 times as great as the respective average field results. Table 2 gives the tests of four sands from Albay, all of which are satisfactory and compare favorably with those of Ottawa sand. In fact, Quinale River sand mortar gives a higher compressive strength at the end of 28 days than does standard Ottawa sand mortar.

ANTIQUE

The results obtained from concrete specimens made in Antique are interesting examples of extreme aberrancy and are somewhat puzzling, considering the lack of information on the aggregates used. No tests have been made of Antique sands or gravels, and even the origin of the aggregates which were used in making the 1 : 2 : 4 mixtures that gave the extraordinarily low average compressive strengths of 233 and 281 pounds per square inch is not known. The specimens cast of similar concrete and used in constructing Ipil Bridge, though younger, gave the good average strength value of 1,334 pounds per square inch. The results are clearly freakish and indicative of careless field procedure. A preliminary laboratory test of available aggregates for the purpose of choosing the most suitable sand and gravel, coupled with careful field work, would have obviated such irregular results.

BATAAN

The compressive strengths of concrete recorded under Bataan were all obtained from specimens made in the materials testing laboratory of the Bureau of Science. The results are only fair. Specimens made of 1 : 2 : 4 concrete and aged 28 days average only 1,723 pounds per square inch, and 1 : 3 : 6 test pieces of the same age average 889. These low compressive strength values are entirely due to the very fine beach sands used. Table

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands.*

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	ALBAY.				*Days.*	*Days.*	*Days.*	*Days.*
1	None	Dec. 10, 1914			1		27	28
2	Do	do			1		27	28
3	Not known		Limestone screenings, Mauraro Quarry.	Crushed limestone, Mauraro Quarry.				28
4	Do	Dec. 24, 1914	Big Cabraran River	Broken limestone bowlders from Km. 14, Guinobotan-Jovellar Road				31
5	Do	do	Half limestone screenings, half sand from Big Cabraran River.	do				31
6	Do	do	Limestone screenings	do				31
7	Do	do	Guinobatan	do				31
8	Do	Mar. 10, 1915	Sand from Cabraran River.	Limestone from Cabraran River.				36
9	Do	do	do	do				36
10	None	Jan. 25, 1915	Quinale River	Crushed limestone from Mauraro Quarry.	1		27	28
11	Arch, Bridge 8. 1, Guinobatan-Jovellar Road	Apr. 15, 1915						42
12	None	Jan. 27, 1915	Limestone screenings	Crushed limestone from Mauraro Quarry.				
13	Do	do	do	do				
14	Guinobatan-Jovellar bridges, Camalig		Cabraran River	Cabraran River				28
15	Quinale-Libon Bridge 134, Polangui	Sept. 13, 1915	Polangui River	Quinale River	3	11	14	28
16	Manita School, Manita	Sept. 24, 1915	Manita Beach	Manita Beach	13		15	28
17	Bridge 42. 1, Polangui	June 6, 1915	Polangui River (fine)	Polangui River (soft)	15		129	144

18	Do	June 25, 1915						28
19	Not used in any structure	Feb. 6, 1915	Guinobatan	Mauraro Quarry				32
20	Do	do	do	do				32
21	Do	do	do	do				32
	ANTIQUE.							
22	Bungol Bridge, Culasi	Apr. 30, 1915						37
23	Do	May 11, 1915						60
24	Do	Jan. 21, 1916	Beach near Bungol River	Beach	7	2	29	38
25	Ipil Bridge, Barbaza	July 21, 1916	Beach	do	7	7	21	35
	BATAAN.							
26	None	Oct. 30, 1909	Mariveles Beach sand, No. 0.	Mariveles Beach gravel, No. 2.	7		21	28
27	Do	do	do	do	7		21	28
28	Do	do	Mariveles Beach sand, No. 2.	Mariveles Beach gravel, No. 4.	7		21	28
29	Do	do	Mariveles Beach sand, No. 1.	Sisiman crushed andesite. No. 5.	7		21	28
30	Do	do	do	do	7		21	28
31	Do	do	Mariveles Beach, No. 2.	do	7		21	28
32	Do	do	do	do	7		21	28
33	Do	do	Mariveles Beach, No. 1.	Mariveles Beach gravel, No. 3.	7		21	28
34	Do	Oct. 16, 1911	Bataan Beach	Coral fingers from Bataan Beach.	7		21	28
35	Do	do	do	Reef coral from Bataan	7		21	28
	BATANGAS.							
36	Obispo Bridge, Obispo	June 13, 1910						57
37	Do	do						57
38	Munting-Tubig Bridge	do						57
39	Do	do						57
40	Matayuanoc Bridge	Oct. 9, 1915			5	13	10	28

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of agregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	BOHOL.				*Days.*	*Days.*	*Days.*	*Days.*
41	Abatan Bridge, Cortes, floor system	Feb. 16, 1910			11		12	23
42	Abatan Bridge, pier foundation	Feb. 18, 1910			9		12	21
43	Abatan Bridge	Apr. 24, 1910						33
44	Abatan Bridge, panels 1 and 2 numbered from south	June 20, 1910			22		14	36
45	Abatan Bridge, panels 3 and 4	June 21, 1910			21		14	35
46	Abatan Bridge, panels 5 and 6	June 22, 1910			20		14	34
47	Abatan Bridge, north span	July 5, 1910						38
48	Do	July 6, 1910						37
49	Do	July 7, 1910						36
50	Do	July 12, 1910						31
51	Calape-Tubigon bridges and culverts	May, 1910						31
52	Do	do						31
53	Do	do						31
54	Inayagan Bridge, Calape-Tubigon Road	do						31
55	Do	do						31
56	Do	do						31
	BULACAN.							
57	Bigaa River Bridge	June 18, 1910						25
	Do	do						25
58	None	Dec. 20, 1911		Bocaue River	7		21	28
59	Do	do		Quingua River	7		21	28
60	Do	do		Bocaue River	7		21	28
61	Do	do		Quingua River	7		21	28
62	Santo Niño Bridge	Dec. 18, 1911						31
63	Do	do						31

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64	Do	Feb. 10, 1912						36
65	None	Dec. 29, 1912	Maasim	Maasim	7		22	29
66	Do	do	Ottawa	do	7		22	29
67	Do	do	Maasim	Baliuag	7		22	29
68	Do	do	Ottawa	do	7		22	29
69	Do	May 1, 1913	San Miguel	San Miguel	7		21	28
70	Do	do	do	do	7		21	28
71	Do	do	do	Sibul	7		21	28
72	Do	do	do	do	7		21	28
73	Malolos Market, footings	Aug. 1, 1915	Pulilan River	Pulilan River				29
74	Do	July 30, 1915	do	do				28
75	Malolos Market, columns	Aug. 7, 1915	do	do				28
76	Do	do	do	do				28
77	Do	do	do	do				28
78	Do	do	do	do				28
79	Do	do	do	do				28
80	Do	Aug. 18 20, 1915	do	do	1	13	14	28
81	Do	do	do	do	1	13	76	90
82	Do	do	do	do	1	13	14	28
83	Do	do	do	do	1	13	76	90
84	Do	do	do	do	1	13	14	28
85	Do	do	do	do	1	13	76	90
86	Do	do	do	do	1	13	14	28
87	Do	do	do	do	1	13	76	90
88	Do	do	do	do	1	13	14	28
89	Do	do	do	do	1	13	76	90
90	Do	Aug. 16, 1915	do	do	1	13	14	28
91	Do	do	do	do	1	13	14	28
92	Do	do	do	do	1	13	14	28
93	Do	Aug. 13, 1915	do	do				28
94	Do	do	do	do				28
95	Do	do	do	do				28
96	Do	Aug. 18, 1915	do	do				181

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	BULACAN—continued.				*Days.*	*Days.*	*Days.*	*Days.*
97	Malolos Market, columns	Aug. 19, 1915	do	do				181
98	Do	Aug. 20, 1915	do	do				181
99	Pulilan Market	Sept. 1, 1915	do	do	1	13	14	28
100	Do	do	do	do	1	13	14	28
101	Do	do	do	do	1	13	14	28
102	Do	Sept. 2, 1915	do	do	1	13	14	28
103	Do	Sept. 1, 1915	do	do	1	13	14	28
104	Do	Aug. 30, 1915	do	do	1	15	11	27
105	Do	Sept. 1, 1915	do	do	1	13	14	28
106	Bagbag Bridge, Calumpit	Nov. 7, 1916	Bagbag River	do	1	1	25	27
107	Do		do	do	1	1	25	27
108	Do		do	do	1	1	25	27
109	Do		Pulilan River	do	1	15	12	28
110	Do		do	do	1	15	12	28
111	Do		do	do	1	13	14	28
112	None	Nov. 23, 1917	Santa Maria River	Santa Maria River	28			28
	CAPIZ.							
113	Capiz Bridge, south and north arch rings	Dec. 11, 1909	Ivisan River	Ivisan River, soft				67
114	Do	Dec. 13, 1909	do	do				69
115	Do	Dec. 14, 1909	do	do				70
116	Ivisan School		Ivisan River, very fine and dirty.	Ivisan Bay, large and not graded.				27
117	Do	Aug. 31, 1915	do	do	1	13	13	27
118	Do	Oct. 15, 1915	Panay River	Santa Barbara	1	13	18	32
119	Do	do	do	do	1	13	18	32

120	Pilar School	Aug. 27, 1915	Pilar Beach (very fine)	Sibala River, large, not graded.	1	13	14	28
121	Do.	do	do	do	1	13	14	28
122	Do.	Oct. 23, 1915	Aranguel River	Sibala River	1	13	14	28
123	Do.	do	do	do	1	13	14	28
124	Libas Bridge, Capiz	Jan. 16, 1917	Panay River	Santa Barbara, Iloilo	1	13	16	30
125	Do.	do	do	do	1	13	16	30
126	Balucuan Bridge, Dao, skew arch	Jan. 15, 1916	Panay River at Dao	do	1	13	15	29
127	Do.	do	do	do	1	13	15	29
128	Do.	Jan. 17, 1916	do	do	1	13	15	29
129	Do.	do	do	do	1	13	15	29
130	Capiz water tank	Oct. 2, 1916	Passi River, Iloilo	do	1	13	19	33
131	Do.	Oct. 3, 1916	do	do	1	13	18	32
132	Do.	Oct. 4, 1916	do	do	1	13	17	31
133	Do.	Oct. 5, 1916	do	do	1	13	16	30
134	Do.	Nov. 3, 1916	do	do	1	13	20	34
135	Do.	Nov. 4, 1916	do	do	1	13	18	32
136	Bridges, Mianay Road, Ivisan, Capiz	Oct. 26, 1916	Km. 12, Ivisan, Mianay River.	Km. 12, Ivisan, Mianay River.	1	13	28	42
137	Do.	do	do	do	1	13	28	42
	CAVITE.							
138	Tabon Bridge, southwest corner and south abutment	Dec. 20, 1910	Pasig River	Pasig River				44
139	Tabon Bridge, center, south abutment	Dec. 21, 1910	do	do				43
140	Tabon Bridge, southeast side, south abutment	Dec. 22, 1910	do	do				42
141	Tabon Bridge, center, north abutment	Dec. 31, 1910	do	do				33
142	Tabon Bridge, spandrel wall	Jan. 2, 1911	do	do				31
143	Do.	do	do	do				46
144	Tabon Bridge, south side ring; north and south abutments.	Jan. 11, 1911	do	do				37
145	Tabon Bridge, spandrel wall	Jan. 12, 1911	do	do				36
146	Tabon Bridge, balustrade, east side	Jan. 15, 1911	do	do				33
147	Tabon Bridge, balustrade, west side	Jan. 19, 1911	do	do				29
148	Cañacao Bridge, piles	Nov. 12, 1915	Mariquina River, coarse, dirty.	Mariquina River	2	13	17	32

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	CAVITE—continued.							
149	Cañacao Bridge, slabs 1 and 2	Jan. 26, 1916	do	do	2	13	13	28
150	Do	Feb. 9, 1916	do	do	1	14	16	31
151	Cañacao Bridge	Feb. 11, 1916	do	do	1	14	14	29
152	Do	Feb. 14, 1916	do	do	1	14	13	28
153	Cañacao Bridge, retaining walls	Mar. 2, 1916	do	do	2	13	13	28
154	Do	Mar. 4, 1916	Mariquina River, sand washed.	do	2	13	13	28
155	Do	Mar. 8, 1916	Mariquina River, washed very clean.	Mariquina River, washed very clean.	2	13	13	28
156	Do	Mar. 9, 1916	Mariquina River, sand very dirty.	Mariquina River, gravel very dirty.	2	13	13	28
157	San Juan culvert 25.3, Noveleta	Oct. 29, 1915	Mariquina River	Mariquina River	2	13	14	29
158	None	Nov. 1, 1916	Rio Grande	Rio Grande	1		27	28
159	Calero Bridge, Noveleta-Cavite Road	Oct. 18, 1916	do	do	2	13	13	28
160	Do	Oct. 20, 1916	do	do	2	13	13	28
161	Do	Oct. 23, 1916	do	do	2	13	11	26
162	Calero Bridge, Noveleta-Cavite Road, piles	Nov. 18, 1916	do	do	13		15	28
163	Culverts, Noveleta-Cavite Road	Nov. 17, 1916	do	do	13		15	28
164	Do	Nov. 18, 1916	do	do	13		15	28
165	None	May, 1916	Imus River	Imus River	28			28
166	Do	Nov., 1916	do	do	1	27		28
167	Do	do	Rio Grande	Rio Grande	1	27		28
	CEBU.							
168	Naga River Bridge	Sept. 7, 1909						28
169	Do	do						28

170	Naga River Bridge, floor	Nov. 16, 1909						30
171	Carcar Bridge, south arch ring	Sept. 12, 1909				14	47	61
172	Carcar Bridge, spandrel wall	Sept. 24, 1909				14	35	49
173	Do	Oct. 6, 1909				14	23	37
174	Do	Oct. 8, 1909				14	21	35
175	None	Mar. 23, 1910	Cebu	Cebu, crushed iron-stained quartz.	7		21	28
176	Do	May 19, 1910	Danao River	Danao River	7		23	30
177	Do	do	Mananga River	Mananga River	7		21	28
178	Do	do	Danao River	Danao River	7		21	28
179	Do	May 21, 1910	Mananga River	Mananga River	7		21	28
180	Osmeña Waterworks, dam	May 22, 1911		Cebu, crushed quartz				29
181	Do	June 23, 1911		3 parts crushed stone, 1 part fine gravel.				36
182	Do	July 29, 1911		Cebu, crushed stone				28
183	Do	Aug. 8, 1911		do				31
184	Do	Aug. 18, 1911		do				28
185	Magallanes Bridge, west abutment	Oct. 15, 1911						31
186	Magallanes Bridge, arch rings	Nov. 5, 1911						30
187	None	Sept. 2, 1912	Mananga River	Mananga River	7		21	28
188	Do	do	do	do	7		21	28
189	Do	Jan. 20, 1913			7		21	28
190	Do	do			7		21	28
191	Do	May 10, 1913	Stream bed, kilometer 115.8 Barili South Road.	Stream bed, kilometer 115.8 Barili South Road.	7		21	28
192	Sibonga Bridge	Nov. 28, 1915	Sibonga Beach	Talisay	15		11	26
193	Do	do	do	do	15		11	26
194	Do	Jan. 4, 1916	do	do	10		17	27
195	Do	Jan. 10, 1916	do	do	10		18	28
196	Cebu Wharf extension	Sept. 2, 1917	Talisay River, coarse	Danao quarry, crushed rock. [f]				297
197	Do	Sept. 3, 1917	do	do				296
198	Do	Sept. 26, 1917	do	do				92
199	Do	Sept. 27, 1917	do	do				91

[f] Danao rock from quarry is a siliceous limestone; coefficient of wear, 3.36; specific gravity, 2.69; rock is proposed for metalling Cebu streets.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	COTABATO.				*Days.*	*Days.*	*Days.*	*Days.*
200	Parang Waterworks, 30 cm. conduit	May 1, 1916	Nituan River	Nituan River	1	13	40	54
201	Parang Waterworks, intake and ram base	do	do	do	1	13	40	54
202	Parang Waterworks	May 26, 1916	do	do	1	13	19	33
203	Parang Waterworks, tank	June 5, 1916	do	do				77
204	Do	July 7, 1916	do	do				55
205	Parang Waterworks, pipe	July 10, 1916	do	do	1	13	38	52
206	Cotabato Light House, accumulator	July 26, 1916	Manila	Manila	1	13	22	36
207	Cotabato Public Hospital, Cotabato	Aug. 18, 1916	Linuac Beach, fine	Dimapatoy River, soft	1	13	42	56
208	Do	Sept. 22, 1916	do	do				43
209	Do	Dec. 15, 1916	do	Dimapatoy River, soft limestone.	1	13	35	49
210	Cotabato River wall, Cotabato, drain pipe	Dec. 4, 1916	do	do	1	13	46	60
	ILOCOS NORTE.							
211	Spillway piles, Gilbert Bridge, Laoag	July 28, 1915	Laoag River	Laoag River				34
212	None	Oct., 1915	do	do	1		27	28
213	Spillway piles, Gilbert Bridge	Oct. 11, 1915	do	do	1	13	16	30
214	Badoc School, Badoc	Dec. 29, 1915	Badoc Beach	Badoc Beach	1	13	15	29
215	Do	Dec. 27, 1915	do	do	1	13	17	31
216	Do	Mar. 22, 1916	do	do	1	13	19	33
217	Do	Mar. 23, 1916	do	do	1	13	19	33
	ILOCOS SUR.							
218	Bridge piles	Oct. 12, 1912						33
219	Do	do						33
220	Cabugao Bridge	Nov. 27, 1912						37
221	Singson Waterworks	Mar. 23, 1915						31

222	Vigan Central School, piers	Aug. 28, 1915	Vigan River	Vigan River	1	13	14	28
223	Vigan Central School	Sept. 22, 1915	Govantes River	Govantes River	1	13	43	57
	ILOILO.							
224	None	Dec. 12, 1910	Sand No. 1	Bridge Site	15		13	28
225	Do	Dec. 19, 1910	do	Crushed siliceous limestone.	15		13	28
226	Do	do	Sand No. 2	do	15		13	28
227	Do	do	Sand No. 3	do	15		13	28
228	Molo Bridge	Jan. 9, 1911	Beach Sand No. 3	Santa Barbara				25
229	Do	do	do	do				25
230	Do	do	do	do				25
231	Do	do	do	do				25
232	Do	Jan. 6, 1911	do	do				29
233	Do	do	do	do				29
234	Do	do	do	do				29
235	Do	do	do	do				29
236	Do	Jan. 17, 1911	do	do				37
237	Do	Jan. 18, 1911	do	do				36
238	Do	Jan. 20, 1911	do	do				34
239	Do	Jan. 23, 1911	do	do				59
240	Do	Jan. 24, 1911	do	do				58
241	Do	Jan. 31, 1911	do	do				51
242	Do	Feb. 4, 1911	do	do				47
243	Do	Feb. 8, 1911	do	do				43
244	Molo Bridge, pier 1	Feb. 11, 1911	Molo Bridge	Santa Barbara pit				44
245	Do	Feb. 14, 1911	do	do				43
246	Molo Bridge	Feb. 16, 1911	do	do				39
247	Do	do	do	do				39
248	Do	do	do	do				39
249	Do	do	do	do				39
250	Molo Bridge, pier 2	Mar. 7, 1911	do	do				41
251	Do	do	do	do				41
252	Do	Mar. 8, 1911	do	do				40
253	Do	Mar. 9, 1911	do	do				39
254	Do	Mar. 14, 1911	do	do				34

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	ILOILO—continued.				*Days.*	*Days.*	*Days.*	*Days.*
255	Molo Bridge, pier 2	Mar. 17, 1911	do	do				31
256	Do	Mar. 20, 1911	do	do				28
257	Molo Bridge	Mar. 31, 1911	do	do				41
258	Molo Bridge, pier 6	May 12, 1911	do	do				40
259	Do	May 13, 1911	do	do				39
260	Molo Bridge, abutment A	May 17, 1911	do	do				35
261	Do	May 24, 1911	do	do				28
262	Do	do	do	do				28
263	Do	May 25, 1911	do	do				27
264	Do	May 30, 1911	do	do				53
265	Do	June 5, 1911	do	do				47
266	Molo Bridge	June 7, 1911	do	do				45
267	Do	June 8, 1911	do	do				44
268	Do	June 9, 1911						43
269	Do	June 17, 1911						35
270	Do	do						35
271	None	June 18, 1911	La Paz, Iloilo	Santa Barbara pit	7		24	31
272	Do	do	do	Oton	7		24	31
273	Molo Bridge, slab 2	July 6, 1911					60	60
274	Do	July 7, 1911					59	59
275	Do	July 8, 1911					58	58
276	Do	July 10, 1911					57	57
277	Do	July 15, 1911					49	49
278	Do	July 14, 1911					50	50
279	Do	July 18, 1911					49	49
280	Do	July 19, 1911					48	48

281	Molo Bridge	do					45	45
282	Do	July 20, 1911					44	44
283	Do	Aug. 1, 1911						35
284	Do	Aug. 3, 1911						32
285	Do	Aug. 4, 1911						31
286	Do	Aug. 5, 1911						30
287	Do	Aug. 7, 1911						28
288	Do	Aug. 16, 1911						38
289	Do	Aug. 17, 1911						37
290	Do	Aug. 24, 1911						30
291	Do	Aug. 25, 1911						29
292	Do	Aug. 26, 1911						41
293	Do	Aug. 28, 1911						39
294	Do	Aug. 29, 1911						38
295	Do	Aug. 31, 1911						36
296	Molo Bridge, span 7	Sept. 13, 1911						40
297	Do	Sept. 15, 1911						38
298	Molo Bridge, span 4	Sept. 27, 1911						34
299	Do	Sept. 29, 1911						32
300	Do	Sept. 30, 1911						31
	ISABELA.							
301	Echague School, piers	Jan. 31, 1916	Cagayan River	Cagayan River	1	13	18	32
302	Echague School, girders	Feb. 11, 1916	do	do	1	13	19	33
303	Echague School, footings	Feb. 12, 1916	do	do				39
304	Cabagan Farm School, footings	Jan. 27, 1917	Cabagan River	Pinac River	1	13	74	88
305	Cabagan Farm School, piers	Feb. 5, 1917	do	do	1	13	65	79
306	Cabagan Farm School, girders	Feb. 12, 1917	do	do	1	13	57	71
307	Cauayan Presidencia	May 10, 1916	Malabulig River	Malabulig River	1	13	31	45
308	Do	Sept. 23, 1916	do	do	1	6	21	28
	JOLO.							
309	None	Apr. 8, 1914	Beach coral and shell débris.	Beach coral	1		27	28
310	Do	do	do	do	1		27	28

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	LAGUNA.				*Days.*	*Days.*	*Days.*	*Days.*
311	None	Oct. 25, 1910	Los Baños, basalt screenings.	Los Baños, crushed basalt from upper ledge.	15		14	29
312	Do.	do	Mogondon sand	do	15		14	29
313	Do.	do	Half basalt screenings, half Mogondon sand.	do	15		13	28
314	Do.	do	do	do	15		13	28
315	Do.	do	Mogondon sand	Los Baños, basalt from lower ledge.	15		15	30
316	Do.	do	do	do	15		15	30
317	Do.	do	Bayog	do	15		15	30
318	Do.	do	do	do	15		15	30
319	San Juan Bridge, Calamba	Dec. 10, 1910						30
320	Do.	do						30
321	San Juan Bridge, abutments	Apr. 1, 1911						39
322	San Juan Bridge	Apr. 21, 1911						29
323	San Juan Bridge; footing, abutment	Apr. 22, 1911						28
324	Do.	Apr. 25, 1911						32
325	San Juan Bridge, pier 3	Apr. 21, 1911						36
326	Do.	Apr. 18, 1911						39
327	Do.	Apr. 26, 1911						31
328	San Juan Bridge	May 1, 1911						40
329	Do.	May 3, 1911						38
330	Do.	May 2, 1911						39
331	San Juan Bridge, footing, abutment A	May 4, 1911						23
332	San Juan Bridge, main arch rings	do						37
333	San Juan Bridge; footing, abutment A	May 5, 1911						22

334	San Juan Bridge, main arch rings	do						36
335	Do	May 6, 1911						35
336	Do	May 8, 1911						33
337	Do	May 9, 1911						32
338	Do	May 10, 1911						31
339	Pagsanjan water tank	Nov. 17, 1918	Pagsanjan River	Pagsanjan River, gravel coarse and highly weathered.	1	13	15	29
340	Do	do	do	do	1	13	15	29
341	Do	do	do	do	1	13	15	29
342	Do	Dec. 8, 1918	do	do	28			28
	LEYTE.							
343	Guinarona Bridge	Mar. 2, 1915						35
344	Barugo School, Barugo	Aug. 4, 1915	Beach	Baluguhay River				27
345	None	Sept. 22, 1915	Beach, fine	Baluguhay River, highly weathered.	1		27	28
346	Do	do	do	do	1		27	28
347	Do	do	do	do	1		27	28
348	Do	do	do	do	1		27	28
349	Barugo School, Barugo	Sept. 5, 1915	do	Baluguhay River	1	14	16	31
350	Do	do	do	do	1	14	16	31
351	Do	Sept. 8, 1915	do	do	1	14	14	29
352	Do	do	do	do	1	14	14	29
353	Do	Nov. 1, 1915	do	do	1	14	14	29
354	Do	Nov. 3, 1915	do	do	1	14	22	37
355	Do	Nov. 9, 1915	do	do	1	14	20	35
356	Tabontabon School, Dagami	Aug. 2, 1915	Tabontabon River	Tabontabon River				29
357	Do		do	do	1	22	6	29
358	Do	Aug. 11, 1915	do	do				28
359	Do	Feb. 16, 1916	do	do	1	14	40	55
360	Mainit Bridge, Alangdang, Leyte	July 28, 1915	Mainit River, fine sand	Mainit River				28
361	Do	Aug. 17, 1915	do	do				28
362	Do	Aug. 21, 1915	do	do				29
363	Do	Sept. 17, 1915	do	do	1	13	14	28

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	LEYTE—continued.							
364	Mainit Bridge, Alangdang, Leyte	Oct. 1, 1915	do	do	1	7	20	28
365	Do	Oct. 8, 1919	do	do	1	8	19	28
366	Do	Oct. 11, 1915	do	do	1	13	14	28
367	Do	Oct. 26, 1915	do	do	1	7	24	32
368	Do	Nov. 6, 1915	do	do	1	14	55	70
369	Do	Nov. 11, 1915	do	do	1	14	55	70
370	Do	do	do	do	1	14	55	70
371	Ormoc Market, Ormoc	Aug. 19, 1915	Ormoc River, fine	Ormoc River, ungraded and large.	1	14	13	28
372	Do	do	Ormoc River	do	1	14	13	28
373	Ormoc Market	Sept. 13, 1915	Beach, fine	Ormoc River	1	14	13	29
374	Do	Nov. 27, 1915	Ormoc River, Km. 2	do	1	14	12	27
375	Do	Nov. 30, 1915	do	do	1	14	13	28
376	Naval School, Leyte	Sept. 13, 1915	Beach	Naval, soft	1	14	13	28
377	Do	Jan. 11, 1916	do	do	1	13	22	36
378	Do	Jan. 26, 1916	do	do	1	13	21	35
379	Hilongos Market	Sept. 9, 1915	Beach, fine	Salog River	1	14	13	28
380	Do	do	do	do	1	14	13	28
381	Do	Sept. 29, 1915	Hilongos Beach	do	1	14	22	37
382	Do	do	do	do	1	14	22	37
383	Do	Oct. 5, 1915	do	do	1	14	16	31
384	Hilongos Market (floor)	Mar. 22, 1916	do	do	1	16	12	29
385	Do	Mar. 23, 1916	do	do	1	16	13	30
386	Punong Bridge, Bato	Sept. 7, 1915	Beach, fine	Beach	1	13	16	30
387	Do	Oct. 15, 1915	Hilongos River	do	1	14	16	31
388	Taghaligue Bridge, Matalom	Aug. 19, 1915	Beach, fine	do	1	13	33	47

389	Do	Aug. 20, 1915	do	do	1	13	33	47
390	Do	Aug. 29, 1915	do	do	1	13	25	39
391	Do	Aug. 30, 1915	do	do	1	13	22	36
392	Do	Oct. 5, 1915	Hilongos River	Mouth of Matalom River	1	14	16	31
393	Do	Oct. 7, 1915	do	Beach	1	14	16	31
394	Dumog Bridge, Bato	Sept. 20, 1915	Beach, fine	do	1	13	33	47
395	Do	Sept. 21, 1915	do	do	1	13	33	47
396	Do	Oct. 5, 1915	Hilongos River	do	1	14	16	31
397	Albuera School, Ormoc	Sept. 20, 1915	Beach	do	4	10	14	28
398	Do	do	do	do	4	10	14	28
399	Do	Nov. 30, 1915	do	do	1	13	19	33
400	Tanauan School, Tanauan	Sept. 30, 1915	Beach, fine	Tigbao River, soft	1	13	15	29
401	Do	do	do	do	1	13	15	29
402	Do	Mar. 9, 1916	do	Malaguihay	1	13	14	28
403	Do	Mar. 9, 1916	Beach	Malaguihay	1	13	14	28
404	Do	do	do	do	1	13	14	28
405	Do	Mar. 31, 1916	Beach, very fine	do	1	14	13	28
406	Do	Apr. 5, 1916	do	do	1	14	18	33
407	Babay School, Babay		do	Beach	4	10	14	28
408	Do	May 13, 1916	do	do	1	14	41	55
409	Do	Mar. 25, 1916	do	do	1	14	22	37
410	Tabango School, San Isidro	May 29, 1916	Tabango Beach	Tabango Beach	1	14	13	28
411	Do	Aug. 28, 1916	do	do	1	14	13	28
412	Maasim Bridge, Maasim	June 3, 1916	Canturing Beach, fine	Canturing River	4	10	21	35
413	Costa bridges and culverts, Inopacan	June 4, 1916	Inopacan Beach	Inopacan Beach	4	14	16	34
414	Do	June 6, 1916	do	do	4	10	18	32
415	Tacloban Port Works	July 20, 1916	Tigbao River	Tigbao River	1	13	27	41
416	Do	July 24, 1916	do	do	1	13	23	37
417	Tacloban Port Works, column	Aug. 21, 1916	Tigbao River, very fine	do	1	13	33	47
418	Do	Aug. 25, 1916	do	do	1	13	29	43
419	Do	Sept. 1, 1916	Tigbao River	do	1	25	3	29
420	Do	Oct. 5, 1916	do	do	1	13	14	28
421	Tacloban Port Works	Oct. 7, 1916	do	do	1	25	7	33
422	Do	Nov. 4, 1916	Tigbao River, very fine	do	1	13	14	28

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	LEYTE—continued.				*Days.*	*Days.*	*Days.*	*Days.*
423	Tacloban Port Works		do	do	1	13	14	28
424	Do	June 30, 1917	Beach, very fine	do	1	13	17	31
425	Do	June 28, 1917	do	do	1	13	19	33
426	Do	Sept. 25, 1917	do	do	1	14	22	37
427	Academic Building, Tacloban Trade School	June 23, 1917	Mangonbaugon River	do	1	14	23	38
428	Do	July 14, 1917	do	do	1	14	16	31
429	Do	Aug. 21, 1917	do	do	1	14	20	35
430	Do	Aug. 25, 1917	do	do	1	14	16	31
431	Provincial Building, Tacloban	Dec. 1, 1917	Beach, fine	do	1	14	24	39
432	Do	Apr. 4, 1918	do	do	1	14	33	48
433	Dulag Market	Mar. 12, 1918	Dulag Beach	Dulag Beach				28
434	Abuyog Administration Building, Abuyog	do	Abuyog Beach	Abuyog Beach				28
	MANILA.							
435	None	May 21, 1909	Pasig River	Pasig River	25		71	96
436	Do	do	Orani River	Pasig River	25		71	96
437	Do	do	Pasig River	do	25		71	96
438	Do	May 27, 1909	do	do	20		70	90
439	Philippine Medical School, second wall and stairs	Feb. 4, 1910						31
440	Philippine Medical School; roof, floor, east wing	Feb. 14, 1910						28
441	Manila Hotel	Sept. 15, 1910				27	34	61
442	Do	Sept. 16, 1910				27	33	60
443	Do	Sept. 17, 1910				27	32	59
444	Do	Sept. 18, 1910				27	31	58
445	Do	Oct. 26, 1910				7	31	38
446	Do	Oct. 28, 1910				7	29	36

447	Do	Oct. 30, 1910				7	27	34
448	Do	Nov. 29, 1910		Crushed stone from city quarry.	7		34	41
449	Do	Dec. 1, 1910		Gravel	7		32	39
450	Do	Jan. 25, 1911			7		33	40
451	Do	Feb. 2, 1911			7		25	32
452	Fernandez Building							28
453	Warehouse, Calle Roman Soler	June 12, 1914						28
454	Warehouse, Calle Azcarraga	May 25, 1914						28
455	Mariano Uy Chaco Building, walls	June 15, 1914						38
456	Do	do						28
457	Mariano Uy Chaco Building	Aug. 25, 1914						28
458	Roxas Building, columns	June 15, 1914						37
459	Hogar Filipino Building	June 10, 1914						28
460	Family Hotel, corner of Herran and Dakota	Feb. 1915						33
461	Do	April 16, 1915						28
462	Masonic Temple	April 14, 1915						28
463	Do	April 15, 1915						49
464	Do	April 22, 1915						48
								41
465	Do	July 2, 1915	Pasig River	Pasig River	7		21	28
466	Do	do	do	do	7		21	28
467	Do	July, 1915	do	do				28
468	None	Aug. 10, 1915	do	Pasig River, fine gravel	2	13	13	28
469	Do	do	do	Pasig River, coarse gravel.	2	13	13	28
470	Masonic Temple	July 15, 1915	Mariquina River	Mariquina River		7	21	28
471	Do	July 20, 1915	do	do		7	21	28
472	Do	July 21, 1915	do	do		7	21	28
473	Do	July 24, 1915	do	do		7	21	28
474	Masonic Temple	July 28, 1915	Mariquina River	Mariquina River		7	21	28
475	Do	Aug. 4, 1915	Pasig River	Pasig River	1	19	16	36
476	Do	do	do	do	1	19	16	36
477	Columbia Club Addition	July 1, 1915	do	do				28
478	Do	do	do	do				28

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
	MANILA—continued.				*Days.*	*Days.*	*Days.*	*Days.*
479	Columbia Club Addition	Aug. 4, 1915	do	do	1	19	8	28
480	Do	do	do	do	1	19	8	28
481	None	Aug. 10, 1915	do	do	1		27	28
482	Bulkhead between piers 3 and 5	Dec. 16, 1915	Mariquina River	Mariquina River	1	20	15	36
483	Do	Dec. 23, 1915	do	do	1	12	15	28
484	Do		do	do	1	25	4	30
485	Do	Jan. 21, 1916	Pasig River	Pasig River				28
486	Do	Jan. 24, 1916	do	do				25
487	Do	do	do	do				27
488	Do	Mar. 1, 1916	Mariquina River	Mariquina River				37
489	Do	Mar. 2, 1916	do	do				36
490	Do	Mar. 17, 1916	do	do				31
491	Do	Mar. 14, 1916	do	do				28
492	Bulkhead between piers 3 and 5, floor section 7	Mar. 16, 1916	do	do	13	13	2	28
493	Do	Mar. 17, 1916	do	do	13	13	2	28
494	Bulkhead between piers 3 and 5, floor section 8	Mar. 22, 1916	do	do	13	13	2	28
495	Bulkhead between piers 3 and 5	Mar. 1, 1916	do	do	13	13	5	31
496	Do	Mar. 11, 1916	do	do	13	13	15	41
497	Do	Mar. 4, 1916	do	do	13	13	12	38
498	Do	Mar. 6, 1916	do	do	13	13	10	36
499	Do	Mar. 14, 1916	do	do	13	13	3	29
500	Bulkhead between piers 3 and 5, floor section 9	Mar. 31, 1916	do	do	1	13	39	54
501	Bulkhead between piers 3 and 5, beam 2	Apr. 5, 1916	do	do	1	13	35	49
502	Bulkhead between piers 3 and 5, beam 13	Apr. 26, 1916	do	do	1	13	14	28
503	Bulkhead between piers 3 and 5	Apr. 12, 1916	do	do	1	13	20	34
504	Do	May 5, 1916	do	do	1	13	14	28

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505	None	July 20, 1915	do	do	1	19	8	28
506	Philippine School of Arts and Trades, roof	Dec. 8, 1915	Pasig River	Pasig River	1	13	20	34
507	Philippine School of Arts and Trades, girders	Nov. 24, 1915	do	do	1	13	33	37
508	Philippine School of Arts and Trades	Jan. 22, 1916	Mariquina River	Mariquina River	----	----	----	28
509	San José Building, Calle Rosario	Sept. 9, 1915	Pasig River	Pasig River	1	20	31	52
510	Postigo Building, second floor wall	Dec. 15, 1915	Pasig River	Pasig River	1	13	14	28
511	Postigo Building, first floor slab	Dec. 24, 1915	do	do	1	19	8	28
512	Do	Jan. 22, 1916	Mariquina River	Mariquina River	1	14	13	28
513	Engineering Laboratory, University of P. I., foundation and footings.	Dec. 15, 1915	Pasig River	Pasig River	1	13	14	28
514	Engineering Laboratory, University of P. I., walls above floor.	Dec. 29, 1915	do	do	1	13	15	29
515	Engineering Laboratory, University of P. I	Jan. 22, 1916	Mariquina River	Mariquina River	1	13	13	27
516	Spanish Casino	Apr. 13, 1916	Pasig River	Pasig River	3	----	96	99
517	Jones Bridge, caissons	July 7, 1917	Mariquina River	Mariquina River	15	----	54	69
518	Do	Aug. 2, 1917	do	do	15	----	13	28
519	Do	Aug. 8, 1917	do	do	----	----	----	28
520	Do	Sept. 3, 1917	do	do	----	----	----	28
521	U. S. Army Quartermaster Pier 1, concrete from piles	Oct. 12, 1914	Sisiman screenings	Sisiman crushed stone	[1] 240	----	812	1,052
522	Do	do	do	do	[1] 231	[2] 784	36	1,051
523	Do	Oct. 15, 1914	do	do	[1] 240	----	809	1,049
524	Do	Do	do	do	[1] 228	[2] 784	36	1,048
525	Do	Oct. 17, 1914	do	do	[1] 240	----	807	1,047
526	Do	do	do	do	[1] 226	[2] 784	36	1,046
527	Do	Oct. 19, 1914	do	do	[1] 240	----	805	1,045
528	Do	do	do	do	[1] 224	[2] 784	36	1,044
529	Do	Oct. 22, 1914	do	do	[1] 240	----	802	1,042
530	Do	do	do	do	[1] 221	[2] 784	36	1,041
531	Do	Nov. 24, 1913	do	Pasig River	[1] 180	[2] 784	409	1,373
532	Do	do	do	Sisiman crushed stone	[1] 180	----	1,193	1,373
533	Do	do	do	do	[1] 180	[2] 784	409	1,373
534	Do	do	do	do	[1] 180	----	1,193	1,373

[1] Specimens covered with damp sacking.

[2] Specimens submerged in salt water of Manila Bay under Pier 1.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	MARINDUQUE.							
535	Tiguion Bridge 16.1, Gasan	Aug. 9, 1915	Tiguion River	Beach				28
536	Do	Sept. 26, 1915	do	do	1	13	17	31
537	Do	Dec. 10, 1915	do	do	1	13	19	33
538	Do	Dec. 17, 1915	do	do	1	13	15	29
	MISAMIS.							
539	Gusa Central School, footings	Dec. 8, 1910	Beach	Beach				30
540	Gusa Central School, walls	do	do	do				30
541	Gusa Central School, girders	do	do	do				30
542	Cagayan Municipal Market, columns	Jan. 26, 1911						34
543	None	June 9, 1914	Sea, unwashed	Sea, unwashed				28
544	Do	do	Sea, sand washed with fresh water.	Sea, gravel washed with fresh water.				23
545	Do	do	do	do				28
546	Cagayan Central School		Cagayan River					28
	MISCELLANEOUS TESTS.							
547	None	Feb. 26, 1910	Pasig River	Crushed Sisiman andesite	9		21	30
548	Do	do	do	do	9		21	30
549	Do	Aug. 27, 1910	do	Crushed rock from ledge adjoining U. S. Engineer's Quarries on mainland opposite Carabao Island.[k]	15		13	28
550	Do	do	do		15		13	28
551	Do	Oct. 29, 1910						48

552	Do	Oct. 31, 1910						46
553	Do	Nov. 2, 1910						44
554	Do	Nov. 8, 1910						38
555	Do	Nov. 18, 1910						28
	OCCIDENTAL NEGROS.							
556	Bridge 0.40, Pontevedra, La Carlota Road	Apr. 4, 1916	Marayo River	San Enrique				85
557	Bridge 0.40, Pontevedra, La Carlota Road; slab 1	Apr. 28, 1916	Candaguit River	Candaguit River				40
558	Bridge 0.40, Pontevedra, La Carlota Road; slab 5	May 5, 1916	do	do				33
559	Bridge 0.40, Pontevedra, La Carlota Road; slab 7 and abutment 2	May 7, 1916	do	do				31
560	Binalbagan Bridge, Hinigaran	July 1, 1916	Bagacay River	Bagacay River				28
561	Do	June 22, 1916	do	do				37
562	Do	Aug. 28, 1916	do	do				34
563	Do	Aug. 17, 1916	do	do				30
564	Do	Dec. 5, 1916	do	do				41
565	Do	Dec. 12, 1916	do	do				63
566	Binalbagan Bridge, Hinigaran; abutments 1 and 2	Dec. 23, 1916	do	do	14		16	30
567	Binalbagan Bridge, Hinigaran	Jan. 1, 1917	do	do	14		18	32
568	Do	Feb. 16, 1917	do	do	14		33	47
569	Binalbagan Bridge, Hinigaran; abutments 1 and 2	Feb. 26, 1917	do	do	14		23	37
570	Bridge 36.5, Bago; abutment 2	Mar. 8, 1917	Maragandang River	Maragandang River	1	13	13	27
571	Bridge 36.5, Bago; abutment 1	Apr. 16, 1917	do	do	1	13	16	30
572	Do	Apr. 23, 1917	do	do	1	13	42	56
573	Presidencia, Bago; foundation and wall	June 24, 1917	Bago River	Bago River	1	14	81	96
574	Presidencia, Bago; first floor	Aug. 26, 1917	do	do	1	13	20	34
575	Presidencia, Bago; second floor	June 27, 1917	do	do	1	14	78	93
576	Bridge 42.0, Pontevedra	Sept. 8, 1917	Candaguit River	Candaguit River	1	13	24	38
577	Do	Oct. 1, 1917	do	do	1	13	28	42
578	Bridge 42.0, Pontevedra; second north abutment	Nov. 20, 1917	do	do				36
579	Sumag Bridge, Bacolod; abutment	Oct. 1, 1917	Sumag Beach	Masungay River				67
580	Sumag Bridge, Bacolod; first pile cap	Oct. 3, 1917	do	do				65
581	Sumag Bridge, Bacolod; second pile cap	Oct. 13, 1917	do	do				55
582	Sumag Bridge, first girder span	Oct. 17, 1917	do	do				42

[k] Used in fortifications at Carabao and El Fraile.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	OCCIDENTAL NEGROS—continued.							
583	Sumag Bridge	Nov. 2, 1917	Sumag Beach	Masungay River	1	13	24	38
584	Sumag Bridge, gutter	Nov. 8, 1917	do	do	1	13	18	32
585	Do	Nov. 10, 1917	do	do	1	13	16	30
586	Sumag Bridge, fifth girder span	Nov. 15, 1917	do	do	1	13	51	65
587	Sumag Bridge, abutment	Nov. 16, 1917	do	do	1	13	50	64
588	Sumag Bridge, slab	Nov. 22, 1917	do	do	1	13	44	58
589	Sumag Bridge, wing wall	Dec. 2, 1917	do	do	1	13	34	48
	ORIENTAL NEGROS.							
590	None	June 22, 1910	Amblan River	Amblan River	15	13		28
591	Do	do	Tanhay River	Tanhay River	15	13		28
592	Do	do	Amblan River	Amblan River	15	13		28
593	Do	do	Tanhay River	Tanhay River	15	13		28
594	Amblan River Bridge, abutment B	June 22, 1911						44
595	Amblan River Bridge, abutment A	June 23, 1911						43
596	Amblan River Bridge, bridge seat abutment A.	June 29, 1911						37
597	Amblan River Bridge, pier 4	July 5, 1911						31
598	Bais Bridge	Feb. 22, 1916	Bais River	Bais River	1	13	29	43
599	Do	Feb. 23, 1916	do	do	1	13	28	42
	NUEVA ECIJA.							
600	Guimba Market, Guimba	Jan. 7, 1916	Binutuan River, dirty sand.	Binutuan River, soft	1	13	14	28
601	Do	do	do	do	1	13	14	28
602	Do	Feb. 23, 1916	Guimba River	Baliuag River	1	13	14	28
603	Do	do	do	do	1	13	14	28

	PALAWAN.							
604	None	Mar. 6, 1917	Coron Beach	Coron Beach	1	27		28
	PAMPANGA.							
605	None	Oct. 22, 1910	Back of troop stables	Crusher-run surface rock	15		13	28
606	Do	do	do	do	15		13	28
607	Do	do	do	Back of troop stables	15		16	31
608	Do	do	do	Banban River	15		16	31
	PANGASINAN.							
609	Bayaoas Bridge	May 9, 1909						33
610	Do	May 11, 1909						31
611	Do	June 19, 1909						31
612	Do	June 21, 1909						29
613	Do	Aug. 2, 1909						30
614	Do	Aug. 6, 1909						26
615	Pantal Bridge, piles	Oct. 16, 1909						23
616	Pantal Bridge, east abutment	Dec. 16, 1909						28
617	Calmay Bridge, piles	Feb. 8, 1910						27
618	Do	Mar. 29, 1910						28
	RIZAL.							
619	Angono Bridge, Binangonan	Feb. 4, 1916	Pasig River	Angono River				28
620	Do	Feb. 7, 1916	do	do				28
621	Do	Mar. 28, 1916	Mariquina River	do				43
622	Do	Mar. 31, 1916	do	do				40
623	Angono Bridge, Binangonan; arch ring	May 18, 1916	do	do				39
624	Do	May 19, 1916	do	do				38
625	San Juan Presidencia, San Juan del Monte	Apr. 26, 1916	do	do				28
626	Bilibiran Bridge, Binangonan pier	May 9. 1916	do	do				31
627	Bilibiran Bridge, Taytay pier	May 11, 1916	do	do				30
	SAMAR.							
628	Bridge 0.7, Calbayog North and South Roads, slabs and girder spans 1 and 2.	May 29 to July 9, 1914						69
629	Bridge 0.7, Calbayog North and South Roads, pile cap, abutment 1.	do						85

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	SAMAR—continued.							
630	Bridge 0.7, Calbayog North and South Roads, pile cap and internal bents 1 and 2.	July 9, 1914						76
631	Do.	do						80
632	Bridge 0.7, Calbayog North and South Roads, pile abutment 2, internal bent 4.	do						66
633	Do.	do						62
634	Bridge 0.7, Calbayog North and South Roads, slabs and girders, span 3.	do						50
635	Bridge 4.3, Calbayog North and South Roads, pile cap, abutment 1, bent 1.	do						47
636	Bridge 19.4, Calbayog North and South Roads, piles	do						89
637	Do.	do						78
638	Bridge 19.4, Calbayog North and South Roads, pile cap, abutment 2, Ilo Bridge.	Oct. 30, 1914						39
639	Bridge 19.4, Calbayog North and South Roads, Ilo Bridge.	Nov. 24, 1914						28
640	Bridge 19.4, Calbayog North and South Roads, Ilo Bridge, slabs 1, 2, and 3.	Mar. 5, 1915						91
641	Bridge 8.9, Calbayog North and South Roads, North abutment, Arapison Bridge.	Oct. 30, 1914						27
642	Bridge 8.9, piles, Arapison Bridge	Dec. 16, 1914						28
643	Bridge 8.9, slab and girders, Arapison Bridge	Mar. 5, 1914						79
		Mar. 24, 1914						76
644	Bridge 9.6, Sorsogon Bridge	Nov. 24, 1914						28
645	Bridge 9.6, piles, Sorsogon Bridge	Dec. 16, 1914						28

646	Bridge 9.6, slab girder 1, Sorsogon Bridge	Mar. 5, 1915						91
647	Bridge 9.6, slab girders 1 and 2, Sorsogon Bridge	do						90
648	Bridge 9.6, Calbayog North and South Roads, slab girders 1 and 2.	do						66
649	Do	do						65
650	Do	do						66
651	Do	do						66
652	Do	do						65
653	Do	do						65
654	Do	do						65
655	Bridge 20.1, 11-meter piles	Mar. 24, 1915						74
656	Bridge 8.1, Guinobatan–Jovellar Road, arch	Apr. 15, 1915						42
657	Culvert, Catbalogan North Road	Nov. 15, 1915	Antiao River	Tagdaranao Beach	1	13	17	31
658	Do	Nov. 12, 1915	do	do	1	13	20	34
659	Culvert, Catbalogan South Road	Apr. 4, 1916	Catbalogan Beach	Tagdaranao Island	1	13	15	29
660	Do	do	do	do	1	13	15	29
661	Cara Bridge, Calbayog	Apr. 14, 1916	Tagdaranao Island	Mararatubig	1	13	14	28
662	Do	Apr. 16, 1916	do	do	1	13	15	29
663	High School, Catbalogan	Sept. 19, 1916	Tagdaranao Beach	Tagdaranao Beach	1	13	14	28
664	Do	Sept. 20, 1916	do	do	1	13	14	28
665	Do	Nov. 2, 1916	Tarangnan Beach	Parasan	1	13	16	30
666	Do	Nov. 2, 1916	do	do	1	13	16	30
667	Do	Nov. 3, 1916	do	do	1	13	15	29
668	School, Basey	Jan. 23, 1918	Tacloban Beach, fine	Osmeña Beach				28
669	Do	do	do	do				28
670	Market booths, Calbayog Market	Apr. 29, 1918	Ipao Beach	Libucan Beach	1	13	23	37
671	Do	May 2, 1918	do	do	1	13	20	34
	SORSOGON.							
672	Sorsogon Court House and Jail	Oct. 26, 1915	Salog River	Salog River	1	13	15	29
673	Do	Oct. 27, 1915	do	do	1	13	15	29
674	Do	Nov. 6, 1915	do	do	1	13	19	33
675	Do	Dec. 14, 1915	do	do	1	13	17	31
676	Do	Dec. 17, 1915	do	do	1	13	44	58
677	Do	Dec. 27, 1915	do	do	1	15	35	51

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			When tested.
			Sand.	Gravel.	Moist air.	Water.	Air.	
					Days.	*Days.*	*Days.*	*Days.*
	SORSOGON—continued.							
678	Sorsogon Court House and jail	Nov. 9, 1915	Salog River	Salog River	1	13	16	30
679	Do	Nov. 15, 1915	do	do	1	13	19	33
	SURIGAO.							
680	Bilang-Bilang Wharf	Dec. 7, 1915	Beach, near wharf	Barrio of Ipil	1		28	29
681	Do	Dec. 14, 1915	do	do				37
682	Do	Dec. 24, 1915	do	do				21
683	Do	Dec. 27, 1915	do	do				35
684	Do	Jan. 8, 1916	do	do				28
685	Do	Jan. 12, 1916	do	do				28
	TAYABAS.							
686	Bridge 14, Pagbilao, Atimonan Road	Sept. 20, 1909						28
687	Do	do						28
688	Trade School, Atimonan	Oct. 6, 1910	Beach	Atimonan				18
689	Do	Dec. 15, 1910	do	do				58
690	Do	do	do	do				58
691	Do	do	do	do				58
692	Do	do	do	do				58
693	Repairs on Dumaca Bridge, Lucena	July 30, 1916	Dumaca River	Dumaca River				29
694	Do	Aug. 1, 1916	do	do				28
695	Do	do	do	do				28
	TARLAC.							
696	San Antonio Bridge, piles	May 8, 1913						25
697	Do							31

698	Divisoria Bridge, piles	July 18, 1913						50
699	Unguit Bridge, slabs	Dec. 5, 1913						49
700	Do	do						49
701	Do	Nov. 22, 1913						62
	ZAMBALES.							
702	Yamot Bridge, abutment 1	Oct. 7, 1916						28
703	Yamot Bridge, intermediate span 1	Oct. 11, 1916						28
704	Yamot Bridge, intermediate span 2	Oct. 16, 1916						28
705	Yamot Bridge, end span	Oct. 17, 1916						28
706	Candelaria Bridge	Oct. 16, 1916	Lauis River	Lauis River				43
707	Do	Oct. 19, 1916	do	do				40
708	Do	Oct. 31, 1916	do	do				28
	ZAMBOANGA.							
709	Zamboanga Waterworks	Jan. 3, 1916	Tumaga River	Tumaga River	2	22	12	36
710	Do	Jan. 4, 1916	do	do	2	14	18	34
711	Do	Jan. 5, 1916	do	do	2	14	19	35
712	Do	Jan. 6, 1916	do	do	2	12	19	33

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	ALBAY.					
1	None	[a] 1	1:2:4	1,977	2,210	Aggregates tested and concrete made at the Bureau of Science.
2	Do	[a] 1	1:3:6	917	1,046	Do.
3	Not known	[a] 3	1:2:4	1,093	1,119	Stone failed in every case; all cubes show numerous voids, some ¼ inch in diameter. Limestone rock very porous and highly weathered. Cubes made by engineer in province.
4	Do	[a] 3	1:3:6	364	507	All mortar failures; cubes honeycombed with air pockets. The faces of the cubes were finished with a neat cement plaster coat 1/16 to ¼ inch thick. The crushed limestone markedly weathered and coated with residual clay; test cubes made by engineer in province.
5	Do	[a] 3	1:3:6	398	614	Do.
6	Do	[a] 3	1:3:6	370	526	Do.
7	Do	[a] 3	1:3:6	504	624	Do.
8	Do	[a] 3	1:2:4	735	773	Gravel sheared in all test specimens. Aggregates intended for use in construction of abutments of Big Cabraran River Bridge; test cubes made by engineer in province.
9	Do	[a] 3	1:2½:5	784	823	Do.
10	None	[a] 1	1:2:4	....	2,946	Stone and mortar failures; concrete made at the Bureau of Science.
11	Arch, Bridge 8.1, Guinobatan-Jovellar Road	[a] 3	1:2:4	....	894	Gravel and mortar failures.
12	None	[a] 2	1:2:4	1,229	1,236	Stone and mortar failures; honeycombed with air pockets; limestone highly weathered and porous; test cubes made by engineer in province in connection with construction of Guinobatan-Jovellar Road.

13	Do	[a]	1:2:4	820	885	Do.
14	Guinobatan-Jovellar Bridges, Camalig	[a] 2	1:1⅔:3⅓	-------	[b] 1,152	Mortar failures.
15	Quinale-Libon Bridge 134, Polangue	[a] 2	1:3:6	724	[b] 763	Gravel soft.
16	Manita School, Manita	[a] 2	1:2½:5	-------	[b] 507	Mortar failures.
17	Bridge 42.1, Polangui	[a] 1	1.15:2:4	-------	1,946	Special test specimen cut from full-sized pile. Block faced on bearing ends and embedded in plaster; area of bearing surface, 45 square inches.
18	Do	[a] 3	1.15:2:4	740	[b] 795	Mortar and gravel failures.
19	Not used in any structure	[a] 3	1:2½:5	1,391	1,440	All stone and mortar failures. These concrete cubes represent experimental mixtures made on the building site in connection with the construction of Guinobatan-Jovellar Bridges.
20	Do	[a] 3	1:2:4	1,200	1,311	Do.
21	Do	[a] 3	1:2¼:4½	1,320	1,442	Do.
	ANTIQUE.					
22	Bungol Bridge, Culasi	[a] 3	1:2:4	191	[b] 233	Mortar failures; Haiphong cement used.
23	Do	[a] 3	1:2:4	207	[b] 281	Do.
24	Do	[a] 6	1:2:4	813	[b] 1,238	Do.
25	Ipil Bridge, Barbaza	[a] 6	1:2:4	1,070	[b] 1,334	Do.
	BATAAN.					
26	None	[a] 2	1:2:4	562	1,201	Mortar and gravel failures; experimental concrete mixtures made in the Bureau of Science; aggregates proposed for Mariveles Quarantine Station Barracks.
27	Do	[a] 1	1:3:6	222	800	Do.
28	Do	[a] 1	1:2:5	968	1,357	Do.
29	Do	[a] 1	1:2:4	560	1,540	Mortar failures; experimental concrete mixtures made in the Bureau of Science; aggregates proposed for Mariveles Quarantine Station Barracks.
30	Do	[a] 1	1:3:6	423	903	Do.
31	Do	[a] 1	1:2:4	1,326	2,105	Do.
32	Do	[a] 1	1:3:6	685	964	Do.
33	Do	[a] 1	1:2:6	468	710	

[a] Test specimens are 6-inch cubes.

[b] Hand mixed.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	BATAAN—continued.					
34	None	[a]1	1:2:4	1,722	1,926	Experimental concrete mixtures made in the Bureau of Science, of aggregates submitted by East Bataan Coal Mining Co.
35	Do	[a]1	1:2:4	1,402	1,842	Do.
	BATANGAS.					
36	Obispo Bridge, Obispo	[a]3	1:2:4	544	1,115	Mortar failures.
37	Do	[a]3	1:3:6	433	1,097	Do.
38	Munting-Tubig Bridge	[a]3	1:2:4	706	1,227	Do.
39	Do	[a]2	1:3:6	317	958	Do.
40	Matayuanoc Bridge	[a]2	1:2:4	450	497	Do.
	BOHOL.					
41	Abatan Bridge, Cortes floor system	[a]3	1:2:4	318	668	Very soft, highly weathered gravel, covered with green algæ (*protococcus*). Considerable quantities of soft coral rock present in gravel; mortar and gravel failures; cubes well made.
42	Abatan Bridge, pier foundation	[a]3	1:2½:5	394	738	Do.
43	Abatan Bridge	[a]2	1:2:4	595	952	Do.
44	Abatan Bridge, panels 1 and 2 numbered from south	[a]2	1:2:4	460	848	Mortar and gravel failures; gravel is composed of coral.
45	Abatan Bridge, panels 2 and 4	[a]2	1:2:4	382	746	Do.
46	Abatan Bridge, panels 5 and 6	[a]2	1:2:4	310	717	Do.
47	Abatan Bridge, north span	[a]3	1:2:4	511	1,093	Mortar and gravel failures; excessive mortar in cubes. Aggregate is composed of soft yellow coral; Green Island cement used.
48	Do	[a]1	1:2:4	342	686	Do.
49	Do	[a]1	1:2:4	261	602	Do.

50	Do.	a2	1:2:4	283	668	Do.
51	Calape-Tubigon Bridge and culverts	a1	1:2:4	224	755	Mortar and gravel failures; concrete very dirty; coarse aggregate is coral.
52	Do.	a1	1:2½:5	509	843	Do.
53	Do.	a1	1:3:6	129	294	Do.
54	Inayagan Bridge, Calape-Tubigon Road	a1	1:2:4	245	815	Mortar and gravel failures; gravel very soft.
55	Do.	a1	1:2½:5	306	949	
56	Do.	a1	1:3:6	658	719	
	BULACAN.					
57	Bigaa River Bridge	a3	1:2:4	135	606	Mortar failures; concrete from floor.
	Do.	a3	1:2½:5	156	495	
58	None	a1	1:2:4	2,264	2,478	Experimental mixture made in the Bureau of Science of aggregates proposed for construction of Santo Niño Bridge.
59	Do.	a1	1:2:4	2,444	2,654	Do.
60	Do.	a1	1:3:6	1,028	1,097	Do.
61	Do.	a1	1:3:6	1,167	1,263	Do.
62	Santo Niño Bridge	a2	1:2:4	1,097	1,574	
63	Do.	a1	1:3:6	395	623	
64	Do.	a2	1:3:6	820	1,142	
65	None	a2	1:2:4	1,903	2,039	Experimental mixtures made in the Bureau of Science.
66	Do.	a2	1:2:4	1,764	2,778	Do.
67	Do.	a1	1:2:4	2,055	2,282	Do.
68	Do.	a1	1:2:4	1,555	2,507	Do.
69	Do.	a2	1:2:4	1,576	1,657	Experimental mixtures made in the Bureau of Science of aggregates proposed for Bolo River Bridge.
70	Do.	a2	1:3:6	670	757	Do.
71	Do.	a1	1:2:4	1,611	1,699	Do.
72	Do.	a1	1:3:6	722	833	Do.
73	Malolos Market, footings	a6	1:3:6	574	594	Mortar failures.
74	Do.	a3	1:3:6	742	788	Do.

[a] Test specimens are 6-inch cubes.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	BULACAN—continued.					
75	Malolos Market, columns	[a] 3	1:2:5	437	437	Mortar failures.
76	Do	[a] 3	1:2:5	--------	860	Do.
77	Do	[a] 3	1:2:5	--------	479	Do.
78	Do	[a] 3	1:2:4	--------	773	Do.
79	Do	[a] 3	1:2⅔:4⅓	--------	823	Do.
80	Do	[a] 5	1:1⅔:4⅓	--------	659	Do.
81	Do	[a] 5	1:1⅔:4⅓	--------	1,012	Do.
82	Do	[a] 5	1:2:4	--------	726	Do.
83	Do	[a] 5	1:2:4	--------	1,103	Do.
84	Do	[a] 5	1:2:4	--------	[b] 667	
85	Do	[a] 5	1:2:4	--------	[b] 1,097	
86	Do	[a] 5	1:2:5	--------	[b] 634	
87	Do	[a] 5	1:2:5	--------	[b] 1,018	
88	Do	[a] 5	1:2:5	--------	[b] 621	
89	Do	[a] 5	1:2:5	--------	[b] 988	
90	Do	[a] 3	1:1⅔:4⅓	--------	[b] 857	
91	Do	[a] 3	1:2:4	--------	[b] 594	
92	Do	[a] 6	1:2:4	--------	[b] 831	
93	Do	[a] 6	1:2:4	695	732	
94	Do	[a] 12	1:2:5	--------	865	
95	Do	[a] 6	1:1⅔:4⅓	--------	833	
96	Do	[a] 5	1:1⅔:4⅓	2,366	2,900	
97	Do	[a] 9	1:2:5	1,765	2,680	

98	Do	[a] 10	1:2:4	2,327	3,117	
99	Pulilan Market	[a] 8	1:2:4		[b] 797	Caballo cement and fresh well water used.
100	Do	[a] 9	1:2:4		[b] 1,098	Do.
101	Do	[a] 9	1:2:5½		[b] 410	Do.
102	Do	[a] 9	1:2:5		[b] 835	Mortar failures; aggregates and cement measured by the barrel.
103	Do	[a] 9	1:2:5		[b] 709	Do.
104	Do	[a] 6	1:2:5		[b] 783	Do.
105	Do	[a] 9	1:2:6		[b] 739	Do.
106	Bagbag Bridge, Calumpit	[c] 2	1:2:4	628	[b] 1,166	Mortar failure; Asano cement used.
107	Do	[c] 2	1:3:6	346	[b] 557	Do.
108	Do	[c] 2	1:2½:5	394	[b] 551	Do.
109	Do	[c] 1	1:2:4	798	[b] 1,180	Mortar failures; Rizal cement used.
110	Do	[c] 1	1:2½:5	514	[b] 626	Do.
111	Do	[c] 1	1:3:6	371	448	Do.
112	None	[d] 3	1:2:4		1,328	Mortar failures; experimental concrete mixture made at the Bureau of Science of aggregates proposed for Santa Maria Bridge.
	CAPIZ.					
113	Capiz Bridge, south and north arch rings	[a] 2	1:2:4	766	1,310	Gravel and mortar failures.
114	Do	[a] 1	1:2:4	767	1,719	Do.
115	Do	[a] 1	1:2:4	944	1,782	Do.
116	Ivisan School	[a] 1	1:3:6		[b] 97	Onada cement used.
117	Do	[a] 2	1:2:4		[b] 266	Do.
118	Do	[a] 2	1:2:4		[b] 619	Do.
119	Do	[a] 2	1:3:6		[b] 336	Do.
120	Pilar School	[a] 2	1:2:4	178	[b] 254	
121	Do	[a] 2	1:3:6	170	[b] 243	
122	Do	[a] 2	1:2:4		[b] 629	Mortar failures.
123	Do	[a] 2	1:3:6		[b] 424	Do.
124	Libas Bridge, Capiz	[a] 2	1:3:6	357	[b] 647	Mortar failures; Haiphong cement used.
125	Do	[a] 2	1:2:4	578	[b] 867	Do.
126	Balucuan Bridge, Dao, skew arch	[a] 2	1:2:4	890	[b] 1,434	Do.
127	Do	[a] 2	1:3:6	508	[b] 1,023	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	CAPIZ—continued.					
128	Balucuan Bridge, Dao, skew arch	[a] 2	1:2:4	887	[b] 1,578	Mortar failures, Haiphong cement used.
129	Do	[a] 2	1:3:6	499	[b] 810	Do.
130	Capiz water tank	[c] 2	1:2:4	633	[b] 1,228	Mortar failures; Rizal cement used.
131	Do	[c] 2	1:2:4	830	[b] 1,467	Do.
132	Do	[c] 2	$1:1\frac{1}{2}:4\frac{1}{2}$	570	[b] 764	Do.
133	Do	[c] 2	$1:2\frac{1}{4}:6\frac{3}{4}$	461	[b] 686	Do.
134	Do	[c] 2	$1\frac{1}{4}:2:4$	1,099	[c] 1,571	Do.
135	Do	[c] 2	$1\frac{1}{4}:2:4$	929	[c] 1,143	Do.
136	Bridges, Mianay Road, Ivisan, Capiz	[c] 2	1:2:4	554	[b] 643	Mortar failures; barrels of cement received in poor condition April, 1916, hoops, staves, and heads broken; cement exposed to air, but well stored. Rizal cement used.
137	Do	[c] 2	1:3:6	357	[b] 425	Do.
	CAVITE.					
138	Tabon Bridge, southwest corner and south abutment	[a] 1	$1:3\frac{1}{2}:7$	56	199	Mortar failures; no gravel sheared during test; specimens poorly made.
139	Tabon Bridge, center, south abutment	[a] 1	$1:3\frac{1}{2}:7$	92	276	Do.
140	Tabon Bridge, southeast side, south abutment	[a] 1	$1:3\frac{1}{2}:7$	144	396	Do.
141	Tabon Bridge, center, north abutment	[a] 2	$1:3\frac{1}{2}:7$	234	384	Do.
142	Tabon Bridge, spandrel wall	[a] 1	1:3:6	299	633	Do.
143	Do	[a] 1	1:3:6	532	863	Mortar failures.
144	Tabon Bridge, south side ring; north and south abutments.	[a] 4	1:2:4	365	579	Do.
145	Tabon Bridge, spandrel wall	[a] 2	1:3:6	143	356	Do.

146	Tabon Bridge, balustrade, east side	[a] 1	1:2:4	298	447	Do.
147	Tabon Bridge, balustrade, west side	[a] 1	1:2:4	483	942	Do.
148	Cañacao Bridge, piles	[a] 4	1:2:4	....	[b] 488	Water from brackish well near beach used for mixing concrete; Onada cement used.
149	Cañacao Bridge, slabs 1 and 2	4	1:1½:4½	1,674	[e] 2,203	Mortar and gravel failures; brackish water and Green Island cement used.
150	Do.	4	1:2:4	1,167	[e] 1,846	Do.
151	Cañacao Bridge	4	1:2:4	1,337	[e] 1,763	Do.
152	Do.	4	1:2:4	1,444	[e] 1,996	Do.
153	Cañacao Bridge, retaining walls	[c] 3	1:1½:4½	423	[b] 609	Dirty salt water used in mixing concrete; cylinders stored in salt water 13 days. Rizal cement used.
154	Do.	[c] 3	1:1½:4½	1,225	[b] 1,304	Test specimens stored in salt water 13 days. Fresh water and Rizal cement used.
155	Do.	[c] 3	1:2:4	866	[b] 1,161	Do.
156	Do.	[c] 3	1:2:4	837	[b] 934	Test specimens stored in salt water 13 days; dirty salt water and Rizal cement used.
157	San Juan culvert No. 25.3, Noveleta	[c] 2	1:1.7:2.3	....	[b] 764	Green Island cement used.
158	None	[d] 5	1:1½:3	1,697	[b] 2,394	Caballo cement used. Experimental mixture made at the Bureau of Science of aggregates proposed for Calero Bridge.
159	Calero Bridge, Noveleta-Cavite Road	[c] 1	1:2½:6½	510	[b] 723	Caballo cement used. To every 36 parts by volume of mixing water (artesian) was added 1 part of Truss-con water-proofing paste; mortar failures.
160	Do.	[c] 1	1:1.7:4.3	402	[b] 521	Do.
161	Do.	[c] 2	1:1.7:4.3	477	[b] 739	Do.
162	Calero Bridge, Noveleta-Cavite Road, piles	[c] 2	1:2:4	637	[b] 1,161	Water from artesian well used for mixing concrete.
163	Culverts, Novaleta-Cavite Road	[c] 2	1:2:4	413	[b] 550	Asano cement and artesian water used.
164	Do.	[c] 2	1:2½:6½	363	[b] 441	Do.
165	None	[d] 3	1:2:4	881	[b] 1,588	Experimental mixture made at the Bureau of Science of aggregates proposed for Aguinaldo School.
166	Do.	[a] 3	1:1½:3	785	[b] 1,037	
167	Do.	[a] 3	1:2:4	1,134	[b] 2,913	

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.
[e] Machine mixed.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	CEBU.					
168	Naga River Bridge	[a]1	1:2:4	272	527	Mortar very friable and easily broken with the fingers.
169	Do	[a]1	1:2½:5	135	271	Do.
170	Naga River Bridge, floor	[a]6	1:2:4	385	583	Mortar and gravel failures; gravel fine and very soft.
171	Carcar Bridge, south arch ring	[a]5	1:2:4	1,239	1,557	Mortar and gravel failures; some pieces of gravel 3 inches in diameter.
172	Carcar Bridge, spandrel wall	[a]5	1:2½:5	360	978	Mortar and gravel failures; gravel soft.
173	Do	[a]2	1:2½:5	536	786	Mortar and gravel failures; gravel soft; concrete contains dirt and shells.
174	Do	[a]3	1:2½:5	545	1,236	Mortar and gravel failures.
175	None	[a]2	1:2:4	2,318	2,427	Mortar failures; crushed rock very hard; experimental mixtures made at Bureau of Science of aggregates proposed for dam of Cebu Gravity Water Supply, Osmeña Waterworks.
176	Do	[a]2	1:3:6	427	624	Do.
177	Do	[a]2	1:3:6	771	1,093	Do.
178	Do	[a]2	1:2:4	900	1,429	Mortar and gravel failures; experimental mixtures made at Bureau of Science of aggregates proposed for dam of Cebu Gravity Water Supply, Osmeña Waterworks.
179	Do	[a]2	1:2:4	1,471	1,816	
180	Osmeña Waterworks dam	[a]1	1:2:4	1,014	1,639	
181	Do	[a]1	1:2:4	1,389	1,800	Mortar and gravel failures.
182	Do	[a]1	1:2:4	1,361	1,719	Do.
183	Do	[a]1	1:2:4	1,555	1,884	Do.
184	Do	[a]1	1:2:4	2,944	3,155	Do.

185	Magallanes Bridge, west abutment	[a]4	1:3:6	1,646	2,183	
186	Magallanes Bridge, arch rings	[a]12	1:2:4	1,954	2,659	
187	None	[a]3	1:2:4	1,259	[b]2,546	Experimental mixtures made at the Bureau of Science of aggregates submitted by the Bureau of Navigation.
188	Do	[a]3	1:3:6	1,180	[b]1,380	Do.
189	Do	[a]2	1:2:4	1,327	[b]1,990	Mortar failures; gravel not sheared; experimental mixtures made at the Bureau of Science of aggregates proposed for Cebu Quarantine Station.
190	Do	[a]2	1:2:5	1,555	[b]1,923	Do.
191	Do	[a]1	1:2:4	1,969	[b]2,126	Experimental mixtures made at the Bureau of Science of aggregates proposed for Barili Road bridges.
192	Sibonga Bridge	[a]3	1:2:4	1,030	[b]1,599	Mortar and gravel failures; Asano cement and muddy water from Sibonga River used.
193	Do	[a]3	1:3:6	795	[b]1,002	Mortar failure; muddy Sibonga River water used.
194	Do	[a]1	1:3:6		[b]503	Do.
195	Do	[a]4	1:2:4	1,389	2,274	Mortar and gravel failures.
196	Cebu Wharf extension	[c]3	1:3:6	1,274	[d]1,534	Do.
197	Do	[c]3	1:2½:5		[d]1,664	Mortar and gravel failures; Caballo cement used.
198	Do	[c]3	1:2:4		[d]1,362	Do.
199	Do	[c]3	1:2:4		[d]1,820	Do.
	COTABATO.					
200	Parang Waterworks, 30 cm conduit.	[c]2	1:2:4	813	974	Mortar failures.
201	Parang Waterworks, intake and ram base	[c]2	1:3:6	670	940	Do.
202	Parang Waterworks	[c]2	1:1½:3	719	951	Do.
203	Parang Waterworks, tank	[c]2	1:2:4	1,237	1,445	Do.
204	Do	[c]2	1:2:4	964	1,269	Mortar and gravel failures.
205	Parang Waterworks, pipe	[c]2	1:1½:3	606	1,025	Mortar failures.
206	Cotabato Lighthouse, accumulator	[c]2	1:2:4	619	1,035	Mortar failures; muddy, salty water from Cotabato River used in mixing concrete.
207	Cotabato Public Hospital, Cotabato	[c]2	1:3:6	175	373	Mortar failures; concrete hand-mixed with Cotabato River water.
208	Do	[c]2	1:3:6	556	599	Mortar failures; concrete hand-mixed with spring water.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Machine mixed.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	COTABATO—continued.					
209	Cotabato Public Hospital, Cotabato	[c] 2	1:3:6	1,822	2,119	Mortar and gravel failures; concrete hand-mixed with spring water.
210	Cotabato River wall, Cotabato drain pipe	[c] 2	1:2:4	1,446	1,517	Mortar failures; concrete hand-mixed with muddy Cotabato River water.
	ILOCOS NORTE.					
211	Spillway piles, Gilbert Bridge, Laoag	[a] 3	1:2:4	2,889	[b] 3,111	
212	None	[d] 5	1:2:4	1,289	[b] 1,905	Experimental cubes made at Bureau of Science of aggregates used in piles of spillway, Gilbert Bridge.
213	Spillway, Gilbert Bridge	[a] 2	1:2:4	------	[b] 714	Mortar and gravel failures.
214	Badoc School, Badoc	[c] 2	1:2:4	------	[b] 763	Caballo cement and clear stagnant water from Balaybabuy canal used.
215	Do	[c] 2	1:2½:5	------	[b] 434	Do.
216	Do	[c] 2	1:2:4	1,042	[b] 1,288	Do.
217	Do	[c] 2	1:2½:5	711	[b] 887	Do.
	ILOCOS SUR.					
218	Bridge piles	[a] 3	1:2:4	620	1,384	Mortar failures; sand very fine.
219	Do	[a] 3	1:3:6	264	689	Do.
220	Cabugao Bridge	[a] 6	1:2:4	415	777	
221	Singson Waterworks	[a] 2	1:1½:3	532	548	Mortar failures; failed by splitting in a plane at right angles to bearing surfaces.
222	Vigan Central school, piers	[a] 2	1:2½:5	------	[b] 816	Mortar failures; Emerald cement used.
223	Vigan Central School	[a] 2	1:2:4	------	[b] 617	Do.
	ILOILO.					
224	None	[a] 1	1:2:4	1,042	1,411	Mortar failures; no stone sheared during test; experimental mixtures made at the Bureau of Science of aggregates proposed for the construction of Molo Bridge.

225	Do.	[a] 2	1:2:4	2,088	2,301	Do.
226	Do.	[a] 2	1:2:4	1,896	2,031	Do.
227	Do.	[a] 2	1:2:4	2,347	2,529	Do.
228	Molo Bridge	[a] 3	1:2½:5	796	1,209	Sand and gravel unscreened; soft water used in mixing concrete; Green Island cement employed.
229	Do.	[a] 3	1:2½:5	767	838	Unscreened gravel and screened sand used; salt water and Green Island cement employed.
230	Do.	[a] 3	1:2½:5	859	1,397	Screened gravel and unscreened sand used; salt water and Green Island cement employed.
231	Do.	[a] 3	1:2½:5	673	1,066	Screened sand and gravel used; salt water and Green Island cement employed.
232	Do.	[a] 3	1;3:6	754	1,308	Sand and gravel not screened; fresh water and Green Island cement used.
233	Do.	[a] 3	1:3:6	658	843	Gravel unscreened; sand screened; fresh water and Green Island cement used.
234	Do.	[a] 3	1:3:6	876	1,135	Gravel screened; sand unscreened; fresh water and Green Island cement used.
235	Do.	[a] 2	1:3:6	920	1,202	Gravel and sand screened; fresh water and Green Island cement used.
236	Do.	[a] 3	1:2½:5	1,220	1,955	Mortar and gravel failures.
237	Do.	[a] 2	1:2½:5	1,124	1,858	Do.
238	Do.	[a] 4	1:2½:5	1,690	1,891	Do.
239	Do.	[a] 2	1:3:6	1,139	1,611	Mortar failures.
240	Do.	[a] 2	1:3:6	708	1,490	Do.
241	Do.	[a] 2	1:3:6	638	965	Do.
242	Do.	[a] 3	1:3:6	572	850	Mortar failures; Green Island cement used.
243	Do.	[a] 1	1:2½:5	888	1,228	Do.
244	Molo Bridge, pier 1	[a] 1	1:3:6	872	1,286	Salt water used in mixing concrete; Green Island cement used.
245	Do.	[a] 1	1:3:6	811	969	Do.
246	Molo Bridge	[a] 2	1:2:4	558	975	Sand and gravel not screened; salt water used; Green Island cement used.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	ILOILO—continued.					
247	Molo Bridge	[a] 2	1:2:4	396	700	Sand screened; gravel unscreened; salt water and Green Island cement used.
248	Do	[a] 2	1:2:4	507	781	Sand unscreened; gravel screened; salt water and Green Island cement used.
249	Do	[a] 2	1:2:4	912	1,089	Sand and gravel screened; salt water and Green Island cement used.
250	Molo Bridge, pier 2	[a] 3	1:2½:5	965	1,769	Mortar failures; Green Island cement used.
251	Do	[a] 1	1:3:6	972	1,382	Do.
252	Do	[a] 3	1:2½:5	1,132	1,759	Do.
253	Do	[a] 3	1:2½:5	1,104	1,746	Do.
254	Do	[a] 1	1:3:6	1,230	1,533	Do.
255	Do	[a] 2	1:3:6	481	874	Do.
256	Do	[a] 1	1:3:6	403	1,213	Do.
257	Molo Bridge	[a] 8	1:2½:5	1,622	1,954	
258	Molo Bridge, pier 6	[a] 4	1:2½:5	876	1,597	
259	Do	[a] 2	1:2½:5	527	1,363	
260	Molo Bridge, abutment A	[a] 2	1:3:6	782	1,178	
261	Do	[a] 1	1:3:6	158	786	
262	Do	[a] 1	1:2½:5	1,005	1,178	
263	Do	[a] 1	1:2½:5	380	897	
264	Do	[a] 1	1:3:6	772	979	
265	Do	[a] 1	1:3:6	778	1,100	
266	Molo Bridge	[a] 4	1:2½:5	872	1,232	
267	Do	[a] 4	1:2½:5	906	1,429	

268	Molo Bridge	[a] 1	1:2½:5	597	1,090	
269	Do	[a] 2	1:3:6	840	1,194	
270	Do	[a] 1	1:2½:5	764	1,090	
271	None	[a] 1	1:2:4	2,667	2,715	Mortar failures; experimental mixtures made in the Bureau of Science of aggregates proposed for the construction of Iloilo Prison.
272	Do	[a] 1	1:2:4	2,278	2,352	Do.
273	Molo Bridge, slab 2	[a] 1	1:2:4	1,167	1,310	
274	Do	[a] 1	1:2:4	1,417	1,561	
275	Do	[a] 1	1:2:4	986	1,257	
276	Do	[a] 1	1:2:4	1,097	1,262	
277	Do	[a] 1	1:2:4	1,055	1,394	
278	Do	[a] 1	1:2:4	930	1,200	
279	Do	[a] 1	1:2:4	833	1,207	
280	Do	[a] 1	1:2:4	1,022	1,300	
281	Molo Bridge	[a] 1	1:2½:5	1,041	1,263	
282	Do	[a] 5	1:2½:5	892	1,299	
283	Do	[a] 1	1:3:6	478	593	
284	Do	[a] 2	1:2:4	1,094	1,331	
285	Do	[a] 2	1:2:4	920	1,048	
286	Do	[a] 2	1:2:4	1,000	1,227	
287	Do	[a] 2	1:2:4	1,076	1,421	
288	Do	[a] 2	1:2:4	853	1,158	
289	Do	[a] 2	1:2:4	1,326	1,422	
290	Do	[a] 2	1:2:4	1,083	1,345	
291	Do	[a] 2	1:2:4	819	1,175	
292	Do	[a] 1	1:2:4	944	1,247	
293	Do	[a] 2	1:2:4	1,275	1,406	
294	Do	[a] 2	1:2:4	1,199	1,428	
295	Do	[a] 1	1:2:4	1,000	1,244	
296	Molo Bridge, span 7	[a] 2	1:2:4	1,118	1,473	
297	Do	[a] 2	1:2:4	1,021	1,285	

[a] Test specimens are 6-inch cubes.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	ILOILO—continued.					
298	Molo Bridge, span 4	[a] 2	1:2:4	1,611	1,614	
299	Do	[a] 1	1:2:4	1,076	1,234	
300	Do	[a] 4	1:2:4	1,645	1,700	
	ISABELA.					
301	Echague School, piers	[c] 2	1:2:5	......	[b] 596	Mortar failures; clear lake water used in mixing concrete.
302	Echague School, girders	[c] 2	1:2:4	789	[b] 885	Do.
303	Echague School, footings	[c] 2	1:2½:5	......	[b] 388	Do.
304	Cabagan Farm School, footings	[c] 2	1:2½:5	491	[b] 633	Mortar failures; well water and Asano cement used.
305	Cabagan Farm School, piers	[c] 2	1:2:5	553	[b] 1,173	Do.
306	Cabagan Farm School, girders	[c] 2	1:2:4	827	[b] 1,172	Do.
307	Cauayan Presidencia	[c] 2	1:2:4	919	[b] 1,277	Mortar failures; water from Malabulig Creek and Asano cement used.
308	Do	[c] 2	1:2½:5	412	[b] 811	Do.
	JOLO.					
309	None	[a] 1	1:2:4	1,217	1,217	Experimental mixture made in the Bureau of Science of aggregates sent from Jolo.
310	Do	[a] 1	1:3:6	577	577	Do.
	LAGUNA.					
311	None	[a] 1	1:2:4	1,278	2,880	Crushed basalt from upper ledge and basalt screenings used; experimental mixtures made at the Bureau of Science of aggregates submitted for test by U. S. A. Quartermaster.

312	Do	[a] 1	1:2:4	1,347	1,528	Crushed basalt from upper ledge and sand from barrio of Mogondon used; experimental mixtures made at the Bureau of Science of aggregates submitted for test by U. S. A. Quartermaster.
313	Do	[a] 1	1:2:4	1,936	2,310	Fine aggregate composed of equal parts by volume of screenings and Mogondon sand; experimental mixtures made at the Bureau of Science of aggregates submitted for test by U. S. A. Quartermaster.
314	Do	[a] 1	1:3:6	1,556	2,214	Do.
315	Do	[a] 2	1:2:4	1,225	1,688	Crushed basalt from lower ledge and Mogondon sand used; mortar failures; experimental mixtures made at the Bureau of Science of aggregates submitted for test by U. S. A. Quartermaster.
316	Do	[a] 2	1:3:6	431	825	Do.
317	Do	[a] 2	1:2:4	1,470	2,012	Sand from the barrio of Bayog used; mortar failures.
318	Do	[a] 2	1:3:6	871	1,210	Do.
319	San Juan Bridge, Calamba	[a] 3	1:2:4	1,158	1,841	Mortar failures:
320	Do	[a] 3	1:3:6	999	1,215	Do.
321	San Juan Bridge, abutments	[a] 1	1:3½:7	119	440	
322	San Juan Bridge	[a] 1	1:2:4	1,000	1,217	
323	San Juan Bridge, footing, abutment	[a] 1	1:2:4	611	1,273	
324	Do	[a] 1	1:2½:5	1,222	1,584	
325	San Juan Bridge, pier 3	[a] 2	1:3:6	769	1,220	
326	Do	[a] 1	1:3:6	389	1,105	
327	Do	[a] 1	1:2½:5	875	1,857	
328	San Juan Bridge	[a] 1	1:2:4	441	1,167	
329	Do	[a] 2	1:2:4	378	1,309	
330	Do	[a] 2	1:2:4	535	1,138	
331	San Juan Bridge, footing, abutment A	[a] 1	1:2½:5	389	1,209	
332	San Juan Bridge, main arch rings	[a] 2	1:2:4	674	1,289	
333	San Juan Bridge, footing, abutment A	[a] 2	1:2½:5	1,135	1,434	
334	San Juan Bridge, main arch rings	[a] 2	1:2:4	750	1,367	
335	Do	[a] 2	1:2:4	740	1,200	
336	Do	[a] 2	1:2:4	292	953	

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks
	LAGUNA—continued.					
337	San Juan Bridge, main arch rings	[a] 2	1:2:4	670	1,556	
338	Do	[a] 2	1:2:4	395	900	
339	Pagsanjan water tank	[c] 1	1:2:4	....	[b] 200	Mortar failures; artesian water and Asano cement used.
340	Do	[c] 1	1:2:4	....	[b] 795	Do.
341	Do	[c] 1	1:2:4	....	[b] 978	Do.
342	Do	[a] 3	1:2:4	1,573	2,197	Experimental mixtures made at the Bureau of Science of aggregates used in constructing Barugo School, Barugo.
	LEYTE.					
343	Guinarona Bridge	[g] 1	1:2:4	1,585	1,910	
344	Barugo School, Barugo	[a] 3	1:3:6	108	[b] 130	Caballo cement used.
345	None	[d] 4	1:2:5	1,637	1,989	Mortar and gravel failures; experimental mixtures made at the Bureau of Science of aggregates used in constructing Barugo School.
346	Do	[d] 3	1:1:3:4.3	1,697	1,894	Do.
347	Do	[d] 4	1:2:6.5	945	1,220	Do.
348	Do	[d] 3	1:1.8:5.8	1,601	1,969	Do.
349	Barugo School, Barugo	[a] 3	1:3:6	234	[b] 251	Mortar failures; fresh well water used.
350	Do	[a] 2	1:2:4	457	[b] 582	Do.
351	Do	[a] 2	1:3:6	891	[b] 917	Do.
352	Do	[a] 2	1:2:4	657	[b] 672	Do.
353	Do	[a] 3	1:2:4	....	753	Caballo cement and fresh well water used.
354	Do	[a] 3	1:2:5	....	882	Do.
355	Do	[a] 3	1:2:5	....	673	Do.
356	Tabontabon School, Dagami	[a] 3	1:2:4	120	[b] 177	Caballo cement used.

357	Do.	[a] 3	1:3:6	-------	[b] 606	Do.
358	Do.	[a] 3	1:3:6	98	[b] 154	Mortar very friable and porous.
359	Do.	[c] 3	1:2:4	1,088	[b] 1,244	Mortar and gravel failures; Caballo cement and fresh well water used.
360	Mainit Bridge, Alangdang, Leyte	[a] 3	1:2½:5	1,596	[b] 1,971	Water from Mainit River and Green Island cement used.
361	Do.	[a] 2	1:2:4	830	[e] 830	Water from Mainit River and Green Island cement used; mortar failures.
362	Do.	[a] 2	1:2½:5	-------	[e] 727	Do.
363	Do.	[a] 5	1:3:6	-------	[e] 556	Do.
364	Do.	[a] 3	1:2½:5	-------	[b] 825	Mainit River water and Asano cement used; mortar failures.
365	Do.	[a] 3	1.12:3:6	488	[b] 521	Do.
366	Do.	[a] 5	1.12:3:6	802	[b] 843	Mainit River water and Asano cement used; mortar and gravel failures.
367	Do.	[a] 2	1:3:6	-------	[e] 500	Mainit River water and Culebra cement used; mortar and gravel failures.
368	Do.	[a] 2	1.12:2½:5	-------	[e] 738	Do.
369	Do.	[a] 2	1.12:3:6	-------	[e] 571	Do.
370	Do.	[a] 2	1.12:3:6	-------	[e] 761	Do.
371	Ormoc Market, Ormoc	[a] 3	1:2:4	261	[b] 261	Mortar failures; Caballo cement used.
372	Do.	[a] 3	1:3:6	81	[b] 118	Do.
373	Ormoc Market	[a] 8	1:2:4	943	[b] 1,057	Caballo cement and fresh well water used.
374	Do.	[a] 3	1.2:3:6	894	1,974	Caballo cement and fresh well water used; mortar and gravel failures.
375	Do.	[a] 3	1.2:2:4	1,193	2,527	Caballo cement and Hilongos River water used; mortar failures.
376	Naval School, Leyte	[a] 2	1:2:4	-------	1,123	Caballo cement and fresh well water used; mortar failures.
377	Do.	[a] 3	1:2:4	2,363	3,884	Caballo cement and fresh well water used; mortar and gravel failures.
378	Do.	[a] 3	1:2:4	1,261	3,053	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.
[e] Machine mixed.
[g] Four-inch cube.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	LEYTE—continued.					
379	Hilongos Market	[a] 3	1:2:4	379	[b] 409	Caballo cement and Hilongos River water used; mortar failures.
380	Do	[a] 3	1:3:6		[b] 295	Do.
381	Do	[a] 3	1:2:4	772	[b] 818	Caballo cement and well water used; mortar and gravel failures.
382	Do	[a] 3	1:3:6		[b] 601	Do.
383	Do	[a] 2	1:2:4		[b] 1,080	Do.
384	Hilongos Market (Floor)	[a] 3	1.15:2:4	1,461	[b] 3,383	Do.
385	Do	[a] 3	1.15:3:6	942	[b] 1,719	Caballo cement and fresh well water used; mortar failures.
386	Punong Bridge, Bato	[a] 6	1:2:4	926	[b] 944	Caballo cement and river water used; mortar failures.
387	Do	[a] 2	1:2:4		[b] 1,361	Caballo cement used; mortar failures.
388	Taghaligue Bridge, Matalom	[a] 3	1:3:6		[b] 905	Do.
389	Do	[a] 3	1:3:6		[b] 1,273	Do.
390	Do	[a] 2	1:2:4	340	[b] 367	Do.
391	Do	[a] 3	1:3½:7	488	[b] 513	Do.
392	Do	[a] 2	1:2:4		[b] 1,321	Caballo cement and fresh well water used; mortar and gravel failures.
393	Do	[a] 3	1:2:4		[b] 1,153	Caballo cement and well water used; mortar and gravel failures.
394	Dumog Bridge, Bato	[a] 3	1:2:4	1,276	[b] 1,321	Caballo cement used; mortar and gravel failures.
395	Do	[a] 3	1:2:4	1,475	[b] 1,616	Do.
396	Do	[a] 2	1:2:4		[b] 1,261	Do.
397	Albuera School, Ormoc	[a] 2	1:3:6		[b] 921	Caballo cement and fresh well water used; mortar failures.
398	Do	[a] 2	1:2:4		[b] 719	Do.
399	Do	[a] 2	1:2½:5	1,815	[b] 2,581	Caballo cement and fresh well water used.
400	Tanauan School, Tanauan	[a] 2	1:2:4		450	Caballo cement and fresh well water used; mortar failures.

401	Do	[a] 2	1:3:6		431	Do.
402	Do	[c] 1	1.15:2:5	768	1,075	Do.
403	Do	[c] 1	1.15:2:4	686	[b] 1,163	Asano cement and fresh well water used; mortar failures.
404	Do	[c] 1	1.15:2½:5	572	[b] 842	Do.
405	Do	[c] 2	1:2:4	277	[b] 450	Asano cement and fresh well water used; mortar and gravel failures.
406	Do	[c] 2	1:2:5	743	[b] 907	Do.
407	Babay School, Babay	[a] 2	1:2:4	772	[b] 818	Caballo cement and fresh well water used; mortar and gravel failures.
408	Do	[a] 3	1:2;4	1,890	[b] 3,053	Caballo cement and fresh well water used.
409	Do	[a] 3	1:2:4	1,587	[b] 2,341	Do.
410	Tabango School, San Isidro	[a] 3	1:2:4	1,019	[b] 1,532	Caballo cement and fresh well water used; mortar failures.
411	Do	[a] 3	1:2:4	874	[b] 1,556	Asano cement and fresh well water used.
412	Maasim Bridge, Maasim	[c] 3	1.2:2:4	446	[b] 903	Asano cement and fresh well water used; mortar failures.
413	Costa bridges and culverts, Inopacan	[c] 3	1.15:2:4	766	[b] 977	Do.
414	Do	[c] 2	1.15:3:6	512	[b] 830	Do.
415	Tacloban Port Works	[c] 3	1:2:4	1,011	[b] 1,862	Asano cement and fresh well water used; mortar and gravel failures.
416	Do	[c] 3	1:2½:5	464	[b] 840	Asano cement and fresh well water used; mortar failures.
417	Tacloban Port Works, column	[c] 2	1.2:2:4	535	[b] 987	Asano cement and fresh well water used; mortar and gravel failures.
418	Do	[c] 2	1.2:2:4	711	[b] 878	Do.
419	Do	[c] 3	1.2:2:4	1,275	[b] 1,608	Do.
420	Do	[c] 3	1.2:2½:5	408	[b] 501	Asano cement and fresh well water used; mortar failures.
421	Tacloban Port Works	[c] 3	1:2:6	462	[b] 609	Do.
422	Do	[c] 3	1:2½:5	347	[b] 375	Do.
423	Do	[c] 3	1:2;6	421	[b] 694	Do.
424	Do	[c] 3	1.2:2:4	940	[b] 1,031	Do.
425	Do	[c] 3	1.2:2½:5	677	[b] 1,119	Do.
426	Do	[c] 3	1.2:2:4		[b] 635	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	LEYTE—continued.					
427	Academic Building, Tacloban Trade School	[c] 3	1:2½:5	--------	[b] 600	Rizal cement and fresh well water used.
428	Do	[c] 3	1:2:4	967	[b] 1,125	Rizal cement and fresh well water used; mortar failures.
429	Do	[c] 3	1.2:2½:5	362	[b] 490	Do.
430	Do	[c] 3	1.2:2:4	574	[b] 882	Rizal cement and fresh well water used; mortar and gravel failures.
431	Provincial Building, Tacloban	[c] 3	1.2:2:4	1,641	[b] 1,736	Do.
432	Do	[c] 3	1.2:2:4	--------	[e] 2,210	Caballo cement and fresh well water used; mortar and gravel failures.
433	Dulag Market	[c] 3	1;2:4	751	[b] 919	Caballo cement and well water used; mortar failures.
434	Abuyog Administration Building, Abuyog	[c] 3	1:2:4	730	[b] 931	Do.
	MANILA.					
435	None	[a] 2	1:1.85:5	1,259	1,960	Alsen cement used; gravel screened on 4-mesh sieve (0.203-mesh opening) to remove sand; sand passed 100% through 4-mesh sieve. Mortar and gravel failures; experimental mixtures at the Bureau of Science.
436	Do	[a] 2	1:2.16:5	1,351	1,878	Do.
437	Do	[a] 1	1:2:5	1,178	2,210	Do.
438	Do	[a] 3	1:2.16:5	912	1,542	Do.
439	Philippine Medical School, second wall and stairs	[a] 4	1:2:5	565	[e] 996	
440	Philippine Medical School, roof, floor, east wing	[a] 4	1:2:4½	526	[e] 1,048	
441	Manila Hotel	[a] 1	1:2:4	773	1,019	Gravel washed but not screened; sand used as delivered.
442	Do	[a] 2	1:2:4	815	872	Do.
443	Do	[a] 2	1:2:4	1,082	1,264	Gravel screened but not washed; sand used as delivered.

444	Do.	[a] 2	1:2:4	500	919	Do.
445	Do.	[a] 2	1:2:4	713	981	Mortar failures. Very fine sand.
446	Do.	[a] 2	1:2:4	643	1,045	Do.
447	Do.	[a] 2	1:2:4	488	835	Do.
448	Do.	[a] 5	1:2:4	937	1,616	
449	Do.	[a] 1	1:2:4	830	1,496	
450	Do.	[a] 1	1:2:4	644	1,218	
451	Do.	[a] 1	1:2:4	264	697	
452	Fernandez Building	[a] 1	1:2½:5	536	573	
453	Warehouse, Calle Roman Soler	[a] 1	1:2½:5	200	448	
454	Warehouse, Calle Azcarraga	[a] 1	1:2½:5	278	518	
455	Mariano Uy Chaco Building, walls	[a] 2	1:2½:5	558	743	
456	Do.	[a] 2	1:2:4	687	735	
457	Mariano Uy Chaco Building	[h] 2	1:2½:5	776	1,140	
458	Roxas Building, columns	[a] 1	1:2:4	568	718	
459	Hogar Filipino Building	[h] 2	1:2½:5	565	667	
460	Family Hotel, corner of Herran and Dakota	[h] 4	1:2½:5	228	253	
461	Do.	[h] 2	1:2½:5	441	563	
462	Masonic Temple	[h] 2	1:1½:4½		534	Mortar failures.
463	Do.	[h] 2	1:1½:4½		300	Do.
464	Do.	[h] 2	1:1½:4½		577	Do.
465	Do.	[h] 2	1:1¼:5		[e] 503	
466	Do.	[h] 3	1:1½:5		[e] 611	
467	Do.	[h] 8	1:1½:5		[e] 484	
468	None	[d] 2	1:2:4		[b] 2,784	Experimental mixtures made at the Bureau of Science of aggregates used in Masonic Temple; Green Island cement used.
469	Do.	[d] 2	1:2:4		[b] 2,956	Do.
470	Masonic Temple	[a] 2	1:1½:4½		376	Green Island cement used.
471	Do.	[a] 2	1:1½:4½		673	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.
[e] Machine mixed.
[h] Test specimens are cylinders 6 inches in diameter and 6 inches high.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	MANILA—continued.					
472	Masonic Temple	[a]2	1:1½:4½		254	Green Island cement used.
473	Do	[a]2	1:1½:4½		673	Do.
474	Do	[a]2	1:1½:4½		254	Do.
475	Do	[b]3	1:1¼:3½		1,199	Do.
476	Do	[b]3	1:1½:4		621	Do.
477	Columbia Club Addition	[b]2	1:2:4		393	Dragon cement used.
478	Do	[b]2	1:2:5		360	Do.
479	Do	[b]3	1:2:4		652	Do.
480	Do	[b]3	1:1:3½		622	Do.
481	None	[d]3	1:2:4		2,652	Experimental mixtures made at the Bureau of Science of aggregates used in construction of bulkheads between piers 3 and 5; Green Island cement used.
482	Bulkhead between piers 3 and 5	[c]3	1:3:6		[e]434	Mortar failures.
483	Do	[c]3	1:2:4		[e]1,304	Mortar and gravel failures.
484	Do	[c]3	1:2½:5		[e]991	Green Island cement used; mortar and gravel failures.
485	Do	[c]2	1:2:4	1,258	[e]1,568	Do.
486	Do	[c]2	1:2:4	920	[e]1,290	Do.
487	Do	[c]2	1:2:4		[e]986	Do.
488	Do	[c]2	1:2:4	1,705	[e]1,820	Rizal cement used.
489	Do	[c]2	1:2:4		[e]1,591	Do.
490	Do	[c]2	1:2:4	1,288	[e]2,093	Rizal cement used; mortar and gravel failures.
491	Do	[c]2	1:2:4	1,633	[e]1,980	Do.
492	Bulkhead between piers 3 and 5, floor section 7	[c]2	1:2:4	787	[e]1,343	Rizal cement used; mortar failures.
493	Do	[c]2	1:2:4	904	[e]1,376	Do.

494	Bulkhead between piers 3 and 5, floor section 8	[c]2	1:2:4	1,050	[e]1,147	Do.
495	Bulkhead between piers 3 and 5	[c]2	1:2½:5	1,102	[e]1,246	Do.
496	Do	[c]1	1:2½:5	1,120	[e]1,356	Do.
497	Do	[c]2	1:3:6	1,122	[e]1,268	Do.
498	Do	[c]2	1:3:6	856	[e]929	Do.
499	Do	[c]2	1:3:6	742	[e]924	Do.
500	Bulkhead between piers 3 and 5, floor section 9	[c]4	1:2:4	727	[e]1,288	Rizal cement used.
501	Bulkhead between piers 3 and 5, beam 2	[c]2	1:2:4	458	[e]729	Do.
502	Bulkhead between piers 3 and 5, beam 13	[c]4	1:3:6	316	[e]393	Do.
503	Bulkhead between piers 3 and 5	[c]2	1:2½:5	675	762	
504	Do	[c]2	1:2½:5	848	1,020	
505	None	[h]5	1:1:3½		[b]1,394	Concrete made in the field; Green Island cement used.
506	Philippine School of Arts and Trades, roof	[c]2	1:2:4		[b]727	Culebra cement used.
507	Philippine School of Arts and Trades, girders	[c]2	1:2:4		[b]1,061	Do.
508	Philippine School of Arts and Trades	[c]2	1:2:4		[b]748	Onada cement used; mortar failures.
509	San Jose Building, Calle Rosario	[h]4	1:2:4	1,289	[b]2,026	Green Island cement used.
510	Postigo Building, second floor wall	[c]2	1:2:4		[b]673	Rizal cement used; mortar failures.
511	Postigo Building, first floor slab	[c]2	1:3:6		[b]484	Do.
512	Do	[c]2	1:2:4	629	[b]814	Asano cement; mortar failures.
513	Engineering Laboratory, University of P. I., foundation and footings.	[c]2	1:2½:5		[b]751	Rizal cement used.
514	Engineering Laboratory, University of P. I., walls above floor.	[c]2	1:2:4		[b]926	Rizal cement used; mortar and gravel failures.
515	Engineering Laboratory, University of P. I	[c]2	1:2:4	876	[b]1,251	Onada cement used.
516	Spanish Casino	[h]6	1:2½:5	435	[b]874	Rizal cement used.
517	Jones Bridge, caisson	[c]6	1:3½:7		[e]731	Caballo cement used; mortar failures.
518	Do	[c]6	1:2:4	697	[e]771	Do.
519	Do	[c]6	1:2:4		[e]1,097	Do.
520	Do	[c]6	1:3½:7		[e]383	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.
[e] Machine mixed.
[h] Test specimens are cylinders 6 inches in diameter and 6 inches high.

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TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch.		Remarks.
				First-crack stress.	Ultimate stress.	
	MANILA—continued.					
521	U. S. Army Quartermaster pier 1, concrete from piles	[a] 1	1:2:4	2,750	[b] 3,874	Asano cement used; mortar and stone failure.
522	Do	[a] 1	1:2:4	2,431	[b] 3,246	Do.
523	Do	[a] 1	1:2:4	3,338	[c] 3,863	Do.
524	Do	[a] 1	1:2:4	1,191	[c] 3,949	Do.
525	Do	[a] 1	1:2:4	1,708	[b] 4,968	Do.
526	Do	[a] 1	1:2:4	1,878	[b] 4,002	Do.
527	Do	[a] 1	1:2:4	2,722	[c] 4,560	Do.
528	Do	[a] 1	1:2:4	1,871	[c] 3,628	Do.
529	Do	[a] 1	1:2:4	2,126	[c] 4,699	Do.
530	Do	[a] 1	1:2:4	------	[c] 4,080	Do.
531	Do	[a] 1	1:2:4	1,568	[b] 1,941	Alsen cement used; mortar and gravel failure.
532	Do	[a] 1	1:2:4	1,615	[b] 4,225	Alsen cement used; mortar and stone failure.
533	Do	[a] 1	1:2:4	2,248	[b] 2,773	Do.
534	Do	[a] 1	1:2:4	4,620	[b] 4,905	Do.
	MARINDUQUE.					
535	Tiguion Bridge 16.1, Gasan	[a] 6	1:2:4	------	[b] 181	Alsen cement used; mortar clearly deficient in cement.
536	Do	[a] 8	1:2:4	------	[b] 251	Alsen cement used; mortar clearly deficient in cement; artesian well water used.
537	Do	[a] 3	1:2:4	959	[b] 1,014	Rizal cement and river water used; mortar and gravel failures.
538	Do	[a] 3	1:2:4	------	[b] 327	Rizal cement and river water used; mortar failures.
	MISAMIS.					
539	Gusa Central School, footings	[a] 1	1:2½:5	469	848	Hemmoor cement used.
540	Gusa Central School, walls	[a] 1	1:2½:4	245	345	Do.

541	Gusa Central School, girders	[a] 1	1:2:4	....	922	Do.
542	Cagayan Municipal Market, columns	[a] 2	1:2:4	834	2,039	Mortar failures.
543	None	[a] 1	1:2:4	612	[b] 1,868	Cubes cast in Cagayan de Misamis by district engineer; Caballo cement and salt water used.
544	Do	[a] 1	1:2:4	556	[b] 1,276	Do.
545	Do	[a] 1	1:2:4	167	[b] 1,563	Caballo cement and fresh water used.
546	Cagayan Central School	[a] 1	1:2½:5	370	[b] 548	Caballo cement used: mortar failures.
	MISCELLANEOUS TESTS.					
547	None	[a] 2	1:2:4	2,271	2,779	Experimental mixtures made at the Bureau of Science of aggregates submitted by the U. S. Engineer's office for fortification construction; Atlas cement used; mortar and gravel failures.
548	Do	[a] 1	1:1½:3	2,038	3,107	Do.
549	Do	[a] 2	1:2:4	2,142	2,606	Do.
550	Do	[a] 2	1:3:6	1,521	1,767	Do.
551	Do	[a] 2	1:2:4	667	829	Submitted by the Constructing Quartermaster, Fort Mills; Haiphong cement used.
552	Do	[a] 1	1:2:4	777	972	Do.
553	Do	[a] 1	1:2:4	339	921	Do.
554	Do	[a] 1	1:2:4	....	1,177	Do.
555	Do	[a] 1	1:2:4	900	1,031	Do.
	OCCIDENTAL NEGROS.					
556	Bridge 0.40, Pontevedra, La Carlota Road	[c] 1	1:2:4	482	[b] 760	Haiphong cement and fresh well water used; mortar failure.
557	Bridge 0.40, Pontevedra, La Carlota Road; slab 1	[c] 1	1:2:4	....	[b] 468	Do.
558	Bridge 0.40, Pontevedra, La Carlota Road; slab 5	[c] 1	1:2:4	....	[b] 667	Do.
559	Bridge 0.40, Pontevedra, La Carlota Road; slab 7 and abutment 2.	[c] 4	1:2:4	....	[b] 640	Do.
560	Binalbagan Bridge, Hinigaran	[c] 2	1:2:4	444	[b] 641	Asano cement and river water used; mortar failures.
561	Do	[c] 2	1:3:6	340	[b] 413	Do.
562	Do	[c] 2	1:2½:5	329	[b] 431	Do.
563	Do	[c] 2	1:2½:5	510	[b] 583	Do.
564	Do	[c] 2	1:2½:5	350	[b] 560	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[e] Machine mixed.

TABLE 8.—*Compressive strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Ultimate stress.	Remarks.
	OCCIDENTAL NEGROS—continued.					
565	Binalbagan Bridge, Hinigaran	[c] 2	1:2½:5	684	[b] 833	Asano cement and river water used; mortar failures.
566	Binalbagan Bridge, Hinigaran; abutments 1 and 2	[c] 2	1:2½:5	416	[e] 552	Do.
567	Binalbagan Bridge, Hinigaran	[c] 2	1:2½:5	543	[e] 651	Do.
568	Do	[c] 2	1:2½:5	490	[e] 532	Do.
569	Binalbagan Bridge, Hinigaran; abutments 1 and 2	[c] 2	1:2½:5	472	[c] 570	Do.
570	Bridge 36.5, Bago; abutment 2	[c] 2	1:3:6	673	[b] 884	
571	Bridge 36.5, Bago; abutment 1	[c] 2	1:2½:5	690	[b] 788	
572	Do	[c] 2	1:2½:5	733	[b] 839	
573	Presidencia, Bago; foundation and wall	[c] 2	1:2½:5	435	[b] 681	Caballo cement and artesian water used; mortar failures.
574	Presidencia, Bago; first floor	[c] 2	1:3:6	342	[b] 467	Do.
575	Presidencia, Bago; second floor	[c] 2	1:2:4		[b] 1,316	Do.
576	Bridge 42.0, Pontevedra	[c] 2	1:3:6	774	[b] 976	Green Island cement and river water used; mortar failures.
577	Do	[c] 3	1:3:6	717	[b] 794	Do.
578	Bridge 42.0, Pontevedra; second north abutment	[c] 2	1:3:6		[b] 799	Do.
579	Sumag Bridge, Bacolod; abutment	[c] 2	1:2:4	1,380	[b] 1,532	Rizal cement and well water used; mortar failures.
580	Sumag Bridge, Bacolod; first pile cap	[c] 2	1:2:4	808	[b] 1,030	Do.
581	Sumag Bridge, Bacolod; second pile cap	[c] 2	1:2:4	614	[b] 851	Do.
582	Sumag Bridge, first girder span	[c] 2	1:2:4	943	[b] 1,063	Do.
583	Sumag Bridge	[c] 2	1:2:4		[b] 1,047	Do.
584	Sumag Bridge, gutter	[c] 2	1:2:4		[b] 756	Do.
585	Do	[c] 2	1:2:4	658	[b] 696	Do.
586	Sumag Bridge, fifth girder span	[c] 2	1:2:4	1,018	[b] 1,114	Rizal cement and well water used; mortar and gravel failures.
587	Sumag Bridge, abutment	[c] 2	1:2:4	1,234	[b] 1,441	Do.

588	Sumag Bridge, slab	[c] 2	1:2:4	----------	[b] 992	Rizal cement and well water used; mortar failures.
589	Sumag Bridge, wing wall	[e] 2	1:2:4	1,018	[b] 1,290	Rizal cement and well water used; mortar and gravel failures.
	ORIENTAL NEGROS.					
590	None	[a] 2	1:2:4	1,938	2,224	Experimental mixtures made at the Bureau of Science of aggregates proposed for Amblan River Bridge; Green Island cement used; mortar failures.
591	Do	[a] 2	1:2:4	1,815	2,282	Do.
592	Do	[a] 1	1:3:6	611	994	Do.
593	Do	[a] 1	1:3:6	966	1,262	Do.
594	Amblan River Bridge, abutment B	[a] 1	1:3:6	500	1,190	
595	Amblan River Bridge, abutment A	[a] 1	1:3:6	778	1,280	
596	Amblan River Bridge, bridge seat abutment A	[a] 1	1:2½:5	389	850	
597	Amblan River Bridge, pier 4	[a] 1	1:3:6	486	705	
598	Bais Bridge	[a] 2	1:2:4	1,273	[b] 1,964	Rizal cement and Bais River water used; mortar failures.
599	Do	[a] 2	1:3:6	867	[b] 1,137	Do.
	NUEVA ECIJA.					
600	Guimba Market, Guimba	[a] 2	1:2:4	----------	[b] 288	Rizal cement and well water used; mortar failures.
601	Do	[a] 2	1:3:6	----------	[b] 246	Do.
602	Do	[a] 2	1:2:4	409	[b] 455	Do.
603	Do	[a] 2	1:2:4	636	[b] 772	Do.
	PALAWAN.					
604	None	[a] 3	1:2:4	1,986	2,443	Experimental mixture made in Bureau of Science of aggregates coming from Coron, and proposed for Coron wharf; mortar and gravel failures.
	PAMPANGA.					
605	None	[a] 1	1:2:4	1,472	2,004	Mortar and gravel failures; experimental mixtures made at the Bureau of Science of aggregates proposed for construction at Camp Stotsenberg.
606	Do	[a] 1	1:2:4	1,222	1,421	Do.
607	Do	[a] 1	1:2:4	1,930	2,171	Do.
608	Do	[a] 1	1:2:4	1,667	2,104	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[e] Machine mixed.

TABLE 8.—*Comparative strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	PANGASINAN.					
609	Bayaoas Bridge	[a] 3	1:2½:5	502	730	
610	Do	[a] 3	1:2:4	1,422	1,546	Mortar failures.
611	Do	[a] 3	1:2½:5	724	1,268	
612	Do	[a] 3	1:2:4	1,403	1,898	Do.
613	Do	[a] 3	1:2:4	658	1,778	Do.
614	Do	[a] 3	1:2½:5	947	1,717	Do.
615	Pantal Bridge, piles	[a] 4	1:2:4	1,291	1,500	Do.
616	Pantal Bridge, east abutment	[a] 4	1:3:6	683	864	Do.
617	Calmay Bridge, piles	[a] 4	1:2:4	1,444	1,710	
618	Do	[a] 2	1:2:4	1,078	1,334	
	RIZAL.					
619	Angono Bridge, Binangonan	[c] 2	1:2:4	490	[b] 558	Rizal cement and river water used; mortar failures.
620	Do	[c] 2	1:3:6	------	[b] 397	Do.
621	Do	[c] 1	1:3:6	756	[c] 857	Do.
622	Do	[c] 1	1:3:6	616	[c] 696	Do.
623	Angono Bridge, Binangonan; arch ring	[c] 2	1:2:4	927	[c] 1,521	Do.
624	Do	[c] 2	1:2:4	681	[c] 1,131	Do.
625	San Juan presidencia, San Juan del Monte	[c] 2	1:2½:5	514	[b] 654	Do.
626	Bilibiran Bridge, Binangonan pier	[c] 2	1:3:6	666	[b] 997	Do.
627	Bilibiran Bridge, Taytay pier	[c] 2	1:3:6	787	[b] 1,091	Do.
	SAMAR.					
628	Bridge 0.7, Calbayog North and South Roads, slabs and girder spans 1 and 2.	[a] 1	1:2:4	1,792	1,903	

629	Bridge 0.7, Calbayog North and South Roads, pile cap, abutment 1.	[a] 1	1:2:4	1,495	1,634	
630	Bridge 0.7, Calbayog North and South Roads, pile cap and internal bents 1 and 2.	[a] 1	1:2:4	654	1,277	
631	Do	[a] 1	1:2:4	--------	1,485	
632	Bridge 0.7, Calbayog North and South Roads, pile abutment 2, internal bent 4.	[a] 1	1:2:4	423	800	
633	Do	[a] 1	1:2:4	2,030	2,241	
634	Bridge 0.7, Calbayog North and South Roads, slabs and girders, span 3.	[a] 1	1:2:4	634	753	
635	Bridge 4.3, Calbayog North and South Roads, pile cap, abutment 1, bent 1.	[a] 1	1:2:4	428	549	
636	Bridge 19.4, Calbayog North and South Roads, piles	[a] 1	1:2:4	518	1,093	
637	Do	[a] 1	1:2:4	--------	975	
638	Bridge 19.4, Calbayog North and South Roads, pile cap, abutment 2, Ilo Bridge.	[a] 1	1:2:4	525	688	Mortar failure.
639	Bridge 19.4, Calbayog North and South Roads, Ilo Bridge.	[a] 2	1:2:4	515	879	Mortar failures.
640	Bridge 19.4, Calbayog North and South Roads, Ilo Bridge, slabs 1, 2, and 3.	[a] 1	1:2:4	--------	698	Mortar failure.
641	Bridge 8.9, Calbayog North and South Roads, North abutment, Arapison Bridge.	[a] 1	1:2:4	--------	330	Do.
642	Bridge 8.9, piles, Arapison Bridge	[a] 2	1:2:4	1,125	1,655	Mortar failures.
643	Bridge 8.9, slabs and girders, Arapison Bridge	[a] 3	1:2:4	434	479	Do.
		[a] 1	1:2:4	--------	358	Mortar failure.
644	Bridge 9.6, Sorsogon Bridge	[a] 1	1:2:4	--------	460	Do.
645	Bridge 9.6, piles, Sorsogon Bridge	[a] 1	1:2:4	500	1,422	Do.
646	Bridge 9.6, slab girder 1, Sorsogon Bridge	[a] 1	1:2:4	--------	698	Do.
647	Bridge 9.6, slab girders 1 and 2, Sorsogon Bridge	[a] 3	1:2:4	578	603	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[e] Machine mixed.

TABLE 8.—*Comparative strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	SAMAR—continued.					
648	Bridge 9.6, Calbayog North and South Roads, slab girders 1 and 2.	[a] 1	1:2:4	1,442	1,581	20 per cent water used in mixing; mortar failure.
649	Do	[a] 1	1:2:4	678	834	22.5 per cent water used in mixing; mortar failure.
650	Do	[a] 1	1:2:4	1,072	1,122	25 per cent water used in mixing; mortar failure.
651	Do	[a] 6	1:2:4	1,190	1,219	27.5 per cent water used in mixing; mortar failure.
652	Do	[a] 1	1:2:4		997	30 per cent water used in mixing; mortar failure.
653	Do	[a] 1	1:2:4		1,252	32.5 per cent water used in mixing; mortar failure.
654	Do	[a] 1	1:2:4		1,028	35 per cent water used in mixing; mortar failure.
655	Bridge 20.1, 11-meter piles	[a] 4	1:2:4		739	Mortar failures.
656	Bridge 8.1, Guinobatan-Jovellar Road, arch	[a] 3	1:2:4		895	
657	Culvert, Catbalogan North Road	[c] 2	1:2:4		[b] 1,058	Fresh well water and Onada cement used; mortar failures.
658	Do	[c] 2	1:3:6		[b] 645	Do.
659	Culvert, Catbalogan South Road	[c] 2	1:2:4	727	[b] 831	Fresh well water and Caballo cement used; mortar failures.
660	Do	[c] 2	1:3:6	672	[b] 806	Do.
661	Cara Bridge, Calbayog	[c] 2	1:2:4		[b] 1,307	Do.
662	Do	[c] 2	1:3:6	631	[b] 964	Do.
663	High School, Catbalogan	[c] 2	1:2:4	506	[b] 703	Fresh well water and Asano cement used; mortar failures.
664	Do	[c] 2	1:3:6	419	[b] 496	Do.
665	Do	[c] 2	1:2:4	783	[b] 1,242	Caballo cement and well water used.
666	Do	[c] 2	1:3:6		[b] 833	Do.
667	Do	[c] 4	1:2:4	1,585	[b] 2,168	Do.
668	School, Basey	[c] 2	1:2:4		[b] 462	Do.
669	Do	[c] 2	1:3:6		[b] 388	Do.

670	Market booths, Calbayog Market	[c] 2	1:2:4		[b] 2,030	Do.
671	Do.	[c] 2	1:3:6		[b] 739	Do.
	SORSOGON.					
672	Sorsogon Court House and Jail	[a] 2	1:2:4		[b] 961	Onada cement and fresh, clear well water used; both cubes failed by splitting at right angles to bearing surfaces; mortar and gravel failures.
673	Do.	[a] 2	1:2:4		[b] 837	Do.
674	Do.	[a] 2	1:2:4		[b] 631	Onada cem nt and well water used.
675	Do.	[a] 2	1:2:4		[b] 554	Do.
676	Do.	[a] 2	1:2:4		[b] 1,016	Do.
677	Do.	[a] 2	1:2:4		[b] 931	Do.
678	Do.	[a] 2	1:2:4		[b] 432	Asano cement and well water used.
679	Do.	[a] 2	1:2:4		[b] 592	Do.
	SURIGAO.					
680	Bilang-Bilang Wharf	[c] 2	1:2:4		[b] 633	Asano cement and surface well water used; mortar failures.
681	Do.	[c] 2	1:2:4		[b] 528	Do.
682	Do.	[c] 2	1:2:4		[b] 642	Do.
683	Do.	[c] 2	1:2:4		[b] 416	Do.
684	Do.	[c] 2	1:2:4		[b] 564	Do.
685	Do.	[c] 2	1:2:4		[b] 570	Do.
	TAYABAS.					
686	Bridge 14, Pagbilao, Atimonan Road	[l] 1	1:2:4	331	619	Mortar and gravel failures; the gravel is very soft and the concrete contains considerable quantities of shell débris.
687	Do.	[l] 1	1:2½:5	438	612	Do.
688	Trade School, Atimonan	[m] 1	1:3:6	200	230	Mortar failure; concrete contains much clay.
689	Do.	[a] 1		169	329	

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[l] Test specimens are 4-inch cubes.
[m] Test specimen is a prism 3¾ by 3¾ by 5⅞ inches.

TABLE 8.—*Comparative strength of Portland cement concrete made in various parts of the Philippine Islands*—Continued.

Tracing No.	Structure in which concrete was used.	Result averaged or specimens broken.	Proportions by volume of cement, sand, and gravel	Compressive strength of concrete, in pounds per square inch. First-crack stress.	Compressive strength of concrete, in pounds per square inch. Ultimate stress.	Remarks.
	TAYABAS—Continued.					
690	Trade School, Atimonan	[a] 1	....	1,000	1,530	
691	Do.	[a] 1	....	281	561	
692	Do.	[a] 1	....	400	825	
693	Repairs on Dumaca Bridge, Lucena	[c] 2	1:3:6	333	[b] 423	Rizal cement and brackish water used; mortar failures.
694	Do.	[c] 2	1:3:6	389	[b] 759	Do.
695	Do.	[c] 2	1:3:6	339	[b] 533	Do.
	TARLAC.					
696	San Antonio Bridge, piles	[a] 5	1:2:4	1,460	2,462	
697	Do.	[a] 6	1:2:4	637	1,046	
698	Divisoria Bridge, piles	[a] 6	1:2:4	1,275	1,575	
699	Unguit Bridge, slabs	[a] 3	1:2:4	708	1,025	
700	Do.	[a] 3	1:2:4	620	887	
701	Do.	[a] 3	1:2:4	528	1,212	
	ZAMBALES.					
702	Yamot Bridge, abutment 1	[c] 2	1:2:4	334	459	Mortar failures.
703	Yamot Bridge, intermediate span 1	[c] 2	1:2:4	311	544	Do.
704	Yamot Bridge, intermediate span 2	[c] 2	1:2:4	260	390	Do.
705	Yamot Bridge, end span	[c] 2	1:2:4	533	1,067	Do.
706	Candelaria Bridge	[c] 1	1:2:4	571	[b] 846	Caballo cement and Yamot River water used; mortar failure.
707	Do.	[c] 1	1:2:4	733	[b] 1,356	Do.
708	Do.	[c] 2	1:2:4	563	[b] 822	Onada cement and Yamot River water used; mortar failures.

	ZAMBOANGA.					
709	Zamboanga Waterworks	[c] 2	1:2:4		[b] 792	Haiphong cement and clear water from Santa Maria canal used; mortar failures.
710	Do.	[c] 2	do	809	[b] 843	Do.
711	Do.	[c] 2	do	810	[b] 927	Caballo cement and clear water from Santa Maria canal used; mortar failures.
712	Do.	[c] 2	do	722	[b] 760	Do.

[a] Test specimens are 6-inch cubes.
[b] Hand mixed.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.

2 gives test data on three Bataan sands, all of which are too fine for high-grade concrete work.

BATANGAS

Tests of concretes coming from Batangas Province are anomalous. The two series of results obtained from 6-inch cubes made of concrete used in Obispo Bridge have practically the same values, 1,115 and 1,097 pounds per square inch, respectively, though the mixtures are apparently differently proportioned, the specimens being marked 1 : 2 : 4 and 1 : 3 : 6, respectively. It is impossible to explain these irregular results, on account of the scanty data available. This laboratory has made no test of Batangas sand or gravel. It is not improbable, however, that these two series of specimens were made from the same batch of concrete, and were subsequently marked as shown in Table 8. Considering the age of the specimens in the first four series (57 days), these concretes must be classed as poor. The two tests of concrete from Matayuanoc Bridge indicate a very inferior product.

BOHOL

Disregarding the small differences in age of the concrete specimens made in Bohol, the compressive strengths average 777, 843, and 507 pounds per square inch for the 1 : 2 : 4, 1 : 2.5 : 5, and 1 : 3 : 6 mixtures, respectively. The 1 : 2.5 : 5 mixtures average stronger than the richer 1 : 2 : 4. No information was sent to this laboratory concerning the source and kind of aggregate used in these specimens, but the débris remaining at the conclusion of the compression tests showed that the sand and gravel were of poor quality; the gravel was very soft, and some of it was covered with green algæ which prevented good bonding. The sand was fine and dirty. All of these tests were made during 1910. Since that time the Bureau of Science has received no concrete specimens from Bohol. Three sands tested during 1917 and 1918 gave poor results; the grains are fine and soft and contain much shell and coral débris. Mortars made from these inferior sands range in tensile strength from 28 to 63 per cent of that of Ottawa sand mortar. It is clear that Bohol concrete aggregates are of inferior quality and unfit for high-grade concrete construction.

BULACAN

As a whole, concrete aggregates from Bulacan are better than the average, and they have given excellent results in the laboratory, though the field tests are too low. Pulilan and Bocaue

River sands particularly, as Table 2 shows, are coarse and have a desirable granulometric composition. The sand used in the construction of Santo Niño Bridge, although rather fine, nevertheless gave an excellent result in the 1 : 2 : 4 field specimens, which averaged 1,574 pounds per square inch. However, field specimens, particularly the 1 : 2 : 4 mixtures, show lower compressive strengths than the corresponding concrete specimens made in the laboratory. The results of laboratory-made 1 : 2 : 4 concrete average 2,158 pounds per square inch, and the corresponding field-made specimens average only 895. The difference in strength of field and laboratory 1 : 3 : 6 concrete is not so great; specimens of this mixture made at the Bureau of Science average 988 pounds per square inch, and those made on the building site, 692. No 1 : 2.5 : 5 or 1 : 2 : 5 mixtures were made in the laboratory; those fabricated in the field average 557 and 702 pounds per square inch, respectively. In general concrete from Bulacan is fair in strength, and in one case the results are very good. With the aggregates available, better field results should have been obtained in the case of the 1 : 2 : 4 mixtures. It is reassuring to note that all of the long-time tests (90 and 181 days) show substantial increases over the 28-day tests.

CAPIZ

Two distinctly different series of results for each of the two groups of 1 : 2 : 4 and 1 : 3 : 6 concrete specimens are characteristic of the tests from Capiz. The 1 : 2 : 4 specimens from Ivisan and Pilar Schools and from Libas Bridge average 527 pounds per square inch, which is about one-third of what concrete of this proportion should test at 28 days. These low results are due to the use of fine, dirty sands from Ivisan and Panay Rivers and from Pilar beach. The 1 : 3 : 6 mixtures involving these sands also give low strengths and average 349 pounds per square inch. The lowest result recorded in this paper was obtained from a concrete specimen coming from Ivisan School, and has a value of only 97 pounds per square inch. Preliminary tests and the exercise of judgment could have prevented the use of these sands for concrete work. In sharp contrast to these low compressive strengths are those obtained from specimens cast of concrete used in the construction of Balucuan Bridge and the Capiz water tank. The 1 : 2 : 4 results from these structures are close together and average 1,427 pounds per square inch. The compressive strength of the 1 : 3 : 6 specimens from Balucuan Bridge average 917 pounds

per square inch, which is practically three times as high as the strength of the other 1 : 3 : 6 mixtures from Capiz Province. Table 2 shows that the sand used in the construction of Balucuan Bridge is coarse, and yields a mortar nearly as strong as that made of standard Ottawa sand. The high compressive strengths of the concretes just cited are due largely to the coarse, clean sands used.

CAVITE

Compressive strengths of concrete specimens from Cavite show a wide degree of variation. Tests of 1 : 2 : 4 cubes from Tabon Bridge average 656 pounds per square inch, which is poor for this class of concrete. The first lot of specimens from Cañacao Bridge made of hand-mixed concrete shows still lower strengths and averages 488 pounds. These results were apparently alarming, for the next lot of specimens sent to the Bureau of Science show great improvement, having been made from machine-mixed concrete; they give the excellent average of 1,868 pounds per square inch. Toward the end of the construction, machine mixing was abandoned and the specimens were again made from hand-mixed concrete, the compressive strength of which is only 1,048 pounds per square inch. The same aggregates were used throughout, so that machine mixing at first glance seems to account for the high strength. Caution must be used in drawing this conclusion, however, because details of proportioning are lacking, and it is not improbable that on account of the crude methods of measuring aggregates in the field, more cement was used in one case than in the other. Concretes mixed in the materials testing laboratory of the Bureau of Science give higher average results than do field-mixed specimens. The 1 : 2 : 4 laboratory mixtures average 2,251 pounds per square inch. Field specimens proportioned 1 : 3 : 6, aged between 31 and 36 days, average 495 pounds per square inch, which incidentally is higher than the lowest result already discussed in the 1 : 2 : 4 series. The mixture 1 : 1.5 : 4.5 was used rather freely in constructing Cañacao Bridge, and the results obtained from these test specimens show extraordinary variation. The highest average result in this series is 2,203 pounds per square inch, and was obtained from machine-mixed concrete; the lowest, 609 pounds per square inch, was given by specimens made from hand-mixed concrete. The entire group of results obtained from 1 : 1.5 : 4.5 concrete specimens gives the good average of 1,319 pounds per square inch. Careful

work would certainly have resulted in more uniform results. Table 2 shows that two of the three sands submitted from Cavite are excellent, and the other is good. Suitable aggregates for concrete work are available in Cavite Province, so that with proper supervision high-testing concrete ought to be the rule.

CEBU

With the exception of the results obtained from Naga River Bridge specimens, the compressive strengths of Cebu concretes are excellent. Excluding the low Naga River Bridge results, and averaging the remaining field compressive strengths obtained from 1 : 2 : 4 concrete specimens having ages between 26 and 28 days, a mean is obtained of 2,091 pounds per square inch, which exceeds by 37 pounds the average compressive strength of the 1 : 2 : 4 concrete specimens made at the Bureau of Science. The field-made 1 : 3 : 6 specimens average considerably higher than laboratory-made test pieces; these results are 1,229 and 1,032 pounds per square inch, respectively. However, the extraordinarily high average result of 2,183 pounds per square inch, gotten from the four 1 : 3 : 6 field specimens representing concrete that was used in the west abutment of Magallanes Bridge, October 15, 1911, should be viewed with suspicion. The probability that the specimens were mislabeled (1 : 3 : 6 for 1 : 2 : 4), or that there was an accidental increase in the quantity of cement used, should not be excluded. By ignoring this doubtful high result, the average of the remaining 1 : 3 : 6 specimens aged 26 to 27 days is reduced to 753 pounds per square inch, which compares favorably with the average of 1,032 pounds obtained from the laboratory-made specimens.

It is interesting to note the great divergency in the compressive strengths of two lots of specimens coming from Sibonga Bridge. Both series of results were obtained from 1 : 3 : 6 concrete of practically the same age and made of the same aggregate, yet one average result is twice that of the other; the compressive strengths are 1,002 and 503 pounds per square inch, respectively. Such discrepancies are not uncommon in the data published in this paper and detract not a little from the reliance that can be placed on these tests. As Table 2 shows, tests of sands from Cebu are fragmentary; no compression tests of mortars were made, but the tensile strength of 1 : 3 mixture shows that Mananga River sand is an excellent concrete aggregate, whereas the other three are of only fair quality.

COTABATO

All of the concrete specimens coming from Cotabato were tested at ages ranging from 33 to 77 days, the majority being over 50 days old. Cotabato is located south of Manila a distance of several days by steamer, and transportation service between the two points is not always regular, so that considerable time is required for specimens to reach Manila. Delay during transit explains the age of the test pieces. Taking into consideration the time that elapsed between the date of manufacture and the date of rupture of these specimens, it will be seen that concrete from Cotabato ranges from poor to fair. The two 1 : 3 : 6 specimens made August 18, 1916, from concrete used in the construction of Cotabato Public Hospital, average 373 pounds per square inch, which is pretty low. Linuac sand used in these cubes is fine-grained, as Table 2 shows, and one would expect a low-testing mortar; but two series of laboratory tests made at two different times, separated by an interval of two years, show that the 1 : 3 mortar is in both cases of practically the same strength as is standard Ottawa sand mortar. The unsatisfactory results obtained from this concrete are therefore not due to poor aggregate but are very likely due to incorrect proportioning of ingredients.

ILOCOS NORTE

Compressive strength results given by concrete specimens coming from Ilocos Norte are so extremely erratic and inconsistent that careless field work is clearly evident. The strength of the 1 : 2 : 4 test pieces made of concrete used in repair work on Gilbert Bridge show a startling variation. The minimum value is 714 pounds per square inch and the maximum 3,111. Concrete used in Badoc School possesses more or less the same variability. The 1 : 2.5 : 5 results vary from 434 to 887 pounds per square inch. Results like these are of little value. By the exercise of due supervision during the proportioning and casting of concrete such freakish results can be obviated.

ILOCOS SUR

The few tests made of concrete cast in Ilocos Sur are characteristically irregular. Mixtures proportioned 1 : 2 : 4 and aged 33 to 37 days gave average ultimate compressive strengths ranging between 777 and 1,384 pounds per square inch, and two test specimens from Vigan Central School, at the age of 57 days, failed at even lower strengths, the average being 617 pounds per square inch. Specimens made of the rich 1 : 1.5 : 3

mixture used in the Singson Waterworks gave anomalous results, the average compressive strength being lower than that shown by either of the leaner mixtures (1 : 2 : 4 and 1 : 3 : 6). Since no preliminary laboratory tests were made of the aggregates employed in Ilocos Sur concretes, it is impossible to hazard an explanation of these abnormalities.

ILOILO

All of the one hundred fifty-six tests of concrete listed under Iloilo in Table 8 were obtained from specimens made in connection with the construction of Molo Bridge. Nine of these results were gotten from laboratory-made test pieces, and the remainder from field-cast specimens molded during the period January 9 to September 30, 1911, so that ample data are available on this structure. More than ordinary care was apparently observed in the erection of this bridge. Before beginning the fabrication of concrete, the district engineer sent samples of several aggregates to the materials testing laboratory during November, 1910, for preliminary examination, and mixing of concrete was begun in January, 1911, of aggregates that had given the best laboratory results. These steps are shown in Table 8 under Iloilo. In general all of the field tests show very good results; they are fairly high and uniform. The 1 : 2 : 4 specimens ranging in age between 28 and 34 days average 1,344 pounds, whereas the corresponding laboratory-made test pieces, having an age that varies between 28 and 31 days, average 2,223 pounds per square inch. However, this catena of results taken as a whole is not free from puzzling anomalisms. For instance, as stated before, the 1 : 2 : 4 specimens aged between 28 and 34 days give a mean compressive strength of 1,344 pounds per square inch, while the group of 1 : 2 : 4 results from specimens next in age, varying between 36 and 41 days, actually show a decrease in compressive strength and average 1,184 pounds per square inch. The remaining results in this 1 : 2 : 4 series average 1,275 pounds per square inch for those having ages between 48 and 50 days, and 1,348 for those aged 57 to 60 days; the last result is practically the same as that given by the youngest specimens. The same irregularity is found in the results obtained from the 1 : 2.5 : 5 and the 1 : 3 : 6 specimens. The former series gives averages of 1,098 pounds per square inch at 25 to 28 days, 1,657 pounds at 34 to 40 days, and 1,408 pounds at 41 to 45 days; the latter series shows 1,068 pounds per square inch at 28 to 35 days, 1,076 pounds at 41 to 51 days,

and 1,556 pounds at 58 to 59 days. It is interesting to note that there is practically no difference in the average compressive strength of the youngest specimens in the 1 : 2.5 : 5 and the 1 : 3 : 6 series, these showing 1,098 and 1,068 pounds per square inch, respectively. With increasing age both give higher results than the richer 1 : 2 : 4 series of corresponding ages. Briquettes made of the four Iloilo sands in the proportion of one part cement to three parts sand all give good tensile strengths. Table 2 shows that the 1 : 3 Iloilo sand mortars at 28 days are, respectively, 79, 91, 95, and 105 per cent as strong as the corresponding Ottawa sand mortars.

ISABELA

Compressive strengths of concrete specimens from Isabela are low. The results given by test pieces coming from Echague School are consistent in that the 1 : 2 : 4 specimens are the strongest, and the 1 : 2.5 : 5 the weakest, the 1 : 2 : 5 coming between. On the other hand there is very little difference between the average strengths of 1 : 2 : 4 and 1 : 2 : 5 specimens coming from Cabagan Farm School which are aged 71 and 79 days, respectively. No laboratory mixture of concrete made of Isabela aggregates was tested, nor has this laboratory ever received either sand or gravel from this province for test.

JOLO

Only two tests, both of laboratory-made mixtures, were made of concrete composed of Jolo aggregates. No field specimens from this province have ever been tested at the Bureau of Science. Both results, as Table 8 shows, are low and unsatisfactory, due largely to the fine, soft, coralline beach sand. These and similar aggregates, which occur abundantly in the Philippines, should under no circumstances be used in concrete work.

LAGUNA

Results obtained from Laguna field-made test specimens, proportioned 1 : 3 : 6 and having ages ranging between 30 and 39 days, show a higher average compressive strength than do those proportioned 1 : 2 : 4 and aged 28 to 33 days; the respective figures are 1,180 and 1,075 pounds per square inch. Field-made 1 : 2 : 4 test pieces aged 35 to 40 days average 1,266 pounds per square inch and are therefore not much better than the younger, 1 : 3 : 6 specimens. Disregarding possible errors, these results show that the 1 : 2 : 4 mixture is uneconomical, since the leaner mixture gives practically the same mean strength at a lower cost per cubic meter. The 1 : 2.5 : 5 field

specimens gave an average result of 1,521 pounds per square inch, which is higher than either of the average results obtained from the 1 : 2 : 4 or the 1 : 3 : 6 specimens made in the field. Average results obtained from laboratory-made specimens are in each case higher than the corresponding mean values given by test pieces made on the building site; 1 : 2 : 4 results average 2,103 pounds per square inch, and 1 : 3 : 6 results average 1,483. Most of the test pieces coming from Laguna were made of concrete used in the construction of San Juan Bridge; no information was sent to this laboratory regarding the source of the aggregate employed in this structure. The 1 : 3 : 6 and the 1 : 2.5 : 5 mixtures gave excellent results, whereas the 1 : 2 : 4 mixture gave only fair values. Laboratory tests made of Pagsanjan sand gave excellent results, but the concrete made in the field with it (for the construction of the Pagsanjan water tank) in one instance gave the very poor strength of 200 pounds per square inch. Careless manipulation apparently accounts for this extremely low result.

LEYTE

Compressive strengths of concrete used in the building of Leyte structures are strikingly incongruous, low, and aberrant. Results obtained from 1 : 2 : 4 specimens aged 28 to 31 days vary between the wide limits of 177 and 1,556 pounds per square inch. The extremely low average of 177 was obtained from three specimens made August 2, 1915, of concrete used in constructing Tabontabon School, at Dagami, Leyte. Since the Tabontabon River sand used in this concrete is of excellent quality, as Table 2 shows, the ridiculously low compressive strength is probably due either to faulty manipulation during mixing and casting, or to incorrect proportioning of cement, or to both causes. There are several other low values in this series of 1 : 2 : 4 mixtures; the three specimens from Ormoc Market, cast August 19, 1915, gave compressive strengths that average 261 pounds per square inch, and those from concrete cast September 30, 1915, and used in Tanauan School average 450. A grand average of the mean values given by the 1 : 2 : 4 specimens having ages between 28 and 31 days gives 907 pounds per square inch as compared with 1,989 pounds obtained from 1 : 2 : 4 specimens made at the Bureau of Science August 4, 1915, of fine beach sand and Baluguhay River gravel. Field-made 1 : 2 : 4 test pieces aged between 35 and 41 days average 1,874 pounds per square inch, and those aged between 47 and 55 days average 1,809, thus showing appreciable increase in

strength with advancing age. Cognizance by those in charge of construction was apparently taken of the poor results given by the 1 : 2 : 4 mixture, and an effort was made to increase the ultimate compressive strength of the concrete by increasing the quantity of cement some 15 per cent. The average result obtained from the 1.2 : 2 : 4 specimens at 29 to 31 days is 1,512 pounds per square inch, and that of older specimens in this series, aged 35 to 48 days, is anomalously lower, being 1,225 pounds per square inch. Mixtures proportioned 1.15 : 2 : 4 and aged 29 to 34 days gave better results, showing a mean value of 1,841 pounds per square inch. Increase in the quantity of cement gave higher results at the end of 28 to 31 days than did the 1 : 2 : 4 mixture; but at later periods the results given by richer mixtures are practically the same as, or less than, those obtained from the leaner mixtures. Comparatively few tests were made of 1 : 2 : 5 and 1 : 2.5 : 5 mixtures. Results obtained from test pieces made of 1 : 2 : 5 concrete aged 29 to 35 days average 821 pounds per square inch, and those given by 1 : 2.5 : 5 specimens aged 28 to 33 days average 1,296, which is much higher than the results given by 1 : 2 : 4 specimens of similar ages. Increasing the percentage of cement in this series to yield the mixtures 1.12 : 2.5 : 5 and 1.2 : 2.5 : 5 gives such anomalous results as to lead one seriously to question the methods of proportioning employed. Increased cement content should increase the compressive strength of the concrete, but the results actually obtained are lower. The 1.2 : 2.5 : 5 specimens aged 28 to 33 days average 810 pounds per square inch, and the 1.12 : 2.5 : 5 test pieces aged 28 to 35 days average 666.

A consideration of the values secured from the 1 : 3 : 6 specimens discloses some of the lowest compressive strengths recorded in this paper, the lowest result, 97 pounds per square inch, being obtained from 1 : 3 : 6 concrete made in Capiz. Concrete from Barugo School averages 130 and 251 pounds per square inch; that from Tabontabon School, 154 pounds; three specimens from Ormoc Market, 118 pounds; and some test specimens made of concrete used in Hilongos Market gave a mean compressive strength of 295 pounds. These results are rather disquieting; if the concrete in the test specimens is representative of that actually used in the respective structures, failures may be expected. The grand average of 444 pounds per square inch is obtained from the values given by the 1 : 3 : 6 specimens aged 27 to 31 days; with aging there is a substantial increase of strength, specimens of this mixture aged 37 to 47 days showing an average of 926 pounds per square inch. An increase in cement con-

tent gave, with one exception, much higher results; at 28 to 32 days the 1.12 : 3 : 6 specimens averaged 979 pounds per square inch, and the 1.2 : 3 : 6 test pieces at 77 days, 1,974. In general the poor results given by concrete made in Leyte are due to the fine-grained sands. The unconformable and inconsistent nature of the compressive strength values is very likely due to faulty proportioning of cement and aggregates.

MANILA AND VICINITY

Most of the concrete specimens made in Manila were marked 1 : 2 : 4; and these, like specimens coming from other provinces, gave widely variant compressive strengths. Test pieces aged 25 to 34 days gave minimum and maximum values of 393 and 2,093 pounds per square inch, respectively, and a mean compressive strength of 1,016 pounds per square inch; the latter value is fair. Aging increases the strength very little; in fact, the average compressive strength given by test pieces aged 52 to 61 days is 1,222 pounds per square inch, which is practically the same as the mean value of 1,292 pounds obtained from specimens aged 36 to 49 days. Laboratory-made 1 : 2 : 4 specimens gave concordant results that average 2,797 pounds per square inch, which is more than twice the average value given by the corresponding series of field-made test pieces.

The fourteen results obtained from specimens made of concrete used in the construction of the United States Quartermaster Pier are particularly noteworthy. This concrete is in a class by itself; it is exceptionally resistant, compact, and stonelike, and on rupture shows no cleavage planes along the surfaces where mortar and stone meet. The five cubes aged 1,042 to 1,052 days kept in air under the materials testing laboratory eaves gave an average compressive strength of 4,393 pounds per square inch. The other five specimens in this series, aged 1,041 to 1,051 days and stored in a steel cage totally submerged under the pier in Manila Bay for a period of 784 days, show marked decrease in average compressive strength; the compressive strength of salt-water specimens averages 3,781 pounds per square inch. Four other specimens, representing concrete from this structure, were ruptured; these were older, and had an age of 1,373 days. There is a well-defined difference between the compressive strength of the specimens submerged in Manila Bay for 784 days and those kept in air, the average being 2,357 and 4,565 pounds per square inch, respectively. The relatively low value of 1,941 pounds per square inch of one of the salt-water specimens is due to the use of soft Pasig sand and gravel, which possess neither the hardness

nor the favorable clean and rough bonding surface characteristic of freshly crushed Sisiman stone and screenings. In both of these series of tests, the weakening effect of salt-water immersion is unmistakably evident. Seventy-seven cubes made of concrete employed in the United States Army Quartermaster Pier are still submerged in Manila Bay, and eighty-eight specimens are being kept in air under the eaves of the materials testing laboratory for long-time tests. Data on these test pieces will be published as soon as possible.

Some other mixtures used in Manila and tested at the Bureau of Science are the 1:2.5:5, the 1:3:6, and the 1:1.5:4.5. The last proportion was used largely in constructing the Masonic Temple, and the results obtained from field-made test specimens are very poor. The compressive strength of test pieces made of 1 : 1.5 : 4.5 concrete and aged 28 days averages as low as 254 pounds per square inch and never exceeds 673, the grand average being 446. With the material available much better results should have been obtained. Older test pieces in this series show practically no gain in strength, the grand average obtained from specimens aged 36 to 49 days being only 483 pounds per square inch. Both of the leaner mixtures 1 : 2.5 : 5 and 1:3:6 gave better average results than did the 1:1.5:4.5 mixtures. At ages ranging from 28 to 34 days the 1 : 2.5 : 5 mixtures gave an average compressive strength of 729 pounds per square inch, which at 38 to 41 days is augmented to 1,005. The 1 : 3 : 6 results average 739 pounds per square inch at 28 to 36 days; this strength is practically the same as that given by the 1 : 2.5 : 5 specimens. One cannot help but be impressed here, as in other instances, with the sameness in the average compressive strength given by specimens made of concrete that is apparently differently proportioned. For all practical purposes there is no difference between the average strengths of the 1 : 2.5 : 5 and 1 : 3 : 6 concretes; and richer mixtures, made of the same aggregate and the same cement, which should show higher strengths, on the contrary, give abnormally lower values. These irregular results seem to point to a faulty method of measuring the cement, so that many of the mixtures tested are deficient in this material. Practically all of the sand used in Manila for concrete work comes from the Pasig and Mariquina River beds. Pasig River sand is fine and is composed of very soft grains of rock in advanced stages of decomposition. It contains little if any quartz and is often contaminated with considerable shell débris. It is a poor concrete aggregate and

should be used with caution. Mariquina River sand is much coarser than that from Pasig River and yields strong mortar of appreciably higher strengths than those given by standard Ottawa sand, as Table 2 shows. Sand from Mariquina River contains practically no quartz and has been derived from the weathering and erosion of andesitic and basaltic rocks. The grains are fairly soft, but excellent results have been obtained from laboratory-made concretes containing this sand, and if due care be exercised there is no reason why Mariquina sand should not give very good results in the field.

Concrete tests, made in connection with the fortification of El Fraile and Carabao Islands at the mouth of Manila Bay, show that laboratory-made specimens are much stronger than those coming from Fort Mills, and those made of 1:2:4 concrete at an age of 28 to 30 days have a mean compressive strength of 2,693 pounds per square inch. Older field specimens made of 1:2:4 concrete, and aged 28 to 38 days, have a mean compressive strength of 1,104 pounds per square inch. Still older cubes made in the field show less strength than this; those 44 to 48 days old average only 907 pounds per square inch. A comparison of the compressive strengths of concrete specimens coming from Fort Mills with those of the provincial test pieces that gave the best results shows the marked superiority of the latter. With the materials available, much better results should have been obtained from the field mixtures here recorded.

MARINDUQUE

With one exception, all results obtained from concrete specimens coming from Marinduque are very poor. Six cubes made on August 19, 1915, of 1 : 2 : 4 concrete used in constructing Tiguion Bridge, at Gasan, are the only specimens tested. The average value shown is 443 pounds per square inch; the minimum, 181; and the maximum, 1,014—results that are certainly extraordinarily erratic. Examination of the spalls and fragments remaining after testing these cubes showed not only that a fine beach sand was used, but also that there was unmistakable deficiency of cement, so that in reality the concrete contained less cement than that required for a 1 : 2 : 4 mixture. Insufficiency of cement is therefore the chief cause for this very low average value of 443 pounds per square inch, which is just about one-fourth of what a good 1 : 2 : 4 concrete should test at 28 days. Varying percentages of cement probably account for the freakish results, no two of which are alike, though nominally

obtained from 1 : 2 : 4 mixtures composed of the same kind of aggregates. More careful proportioning of cement and aggregates would undoubtedly have given more uniform results.

MISAMIS

Good results were obtained from 1: 2: 4 concrete specimens coming from Misamis, the average being 1,534 pounds per square inch for specimens aged 28 to 34 days; the minimum value of 922 pounds per square inch in this series is less than half of the maximum value, 2,039 pounds. The three 1 : 2.5 : 5 test pieces gave low results, which average 698 pounds per square inch. The compressive strength values show that care was taken in proportioning and that concrete materials of good quality are available in this province. One sample of sand from Cagayan River must be classed as excellent. It yielded an extraordinarily resistant 1 : 3 mortar, unsurpassed in compressive strength by any other mortar recorded in this paper. The average ultimate compressive strength, at 28 days, of specimens made with the use of this sand is 5,508 pounds per square inch, which is nearly twice that of specimens made of Ottawa sand. The high strength of this mortar is primarily due to the very coarse and graded granulometric composition of the sand combined with hardness and cleanness of the grains. This sand is composed principally of rounded basaltic pebbles and contains very little quartz.

NUEVA ECIJA

Values obtained from concrete specimens coming from Nueva Ecija are poor, particularly those made of Binutuan River aggregate, which is soft, dirty, and fine-grained. The 1 : 2 : 4 test pieces made of this aggregate gave the extraordinarily low result of 288 pounds per square inch, which is very close to the mean compressive strength of 246 pounds per square inch given by the 1 : 3 : 6 specimens at 28 days, so that it is not improbable that the same mixture was used in casting all four of these specimens. The results were so bad that the district engineer was ordered to use a different aggregate. The 1 : 2 : 4 specimens made of Guimba River sand and Baliuag River gravel gave higher compressive strengths; but these values also are unsatisfactory, and, moreover, they are markedly variant. The average given by these four cubes is 614 pounds per square inch. Preliminary laboratory tests of available Nueva Ecija sands would certainly have given valuable information, which would have resulted in the elimination of the unsuitable materials that were unfortunately used in actual construction.

OCCIDENTAL NEGROS

Results obtained from concrete specimens coming from Occidental Negros and marked 1 : 2 : 4, 1 : 2.5 : 5, and 1 : 3 : 6 are so much alike that one is almost forced to conclude that the entire series of test pieces was made from mixtures of more or less the same proportions. Specimens made of 1 : 2 : 4 concrete and aged 28 to 33 days gave an average compressive strength of 681 pounds per square inch; 1 : 2.5 : 5 specimens aged 30 to 34 days average 601 pounds; and the 1 : 3 : 6 test pieces ranging in age from 27 to 42 days average 722 pounds per square inch. With one exception, increasing age brought about increasing compressive strength in the series of test pieces made of 1 : 2 : 4 concrete; those aged 38 to 42 days average 859 pounds per square inch, those aged 48 to 55 days average 1,044, and those aged 64 to 67 days average 1,279. The oldest specimens in this series however, those 85 and 93 days old, respectively, show less strength, and give the mean value of 1,038 pounds per square inch. Test pieces made of 1 : 2.5 : 5 concrete aged 37 to 41 days average 554 pounds per square inch, whereas those aged 56 to 63 days average 836 pounds per square inch. Values obtained from the 1 : 2 : 4 specimens are low and indicate a very poor grade of concrete. Fair strengths were given by the other mixtures. Only one sand coming from Occidental Negros was tested, and the results obtained are very satisfactory, though from field data it seems that this sand was never used in actual construction.

ORIENTAL NEGROS

Results shown by field specimens from Oriental Negros are good, though most of them were obtained from cubes considerably older than those made in the laboratory, so that comparison of the two is unsatisfactory. Laboratory-made concrete proportioned 1 : 2 : 4 at 28 days gives an average compressive strength of 2,253 pounds per square inch. Only two field-made test pieces made of 1 : 2 : 4 were tested, and these at an age of 43 days average 1,964 pounds per square inch. The values given by the field specimens made of 1 : 3 : 6 concrete compare favorably with those obtained from laboratory-made cubes. The latter at 28 days average 1,128 pounds per square inch, and a single test piece of the former at 31 days gives 705 pounds. At ages ranging between 42 and 44 days, field specimens of 1 : 3 : 6 concrete give a mean compressive strength of 1,202 pounds per square inch. Only one sand from Oriental Negros

was tested in the laboratory and the average compressive strength at 28 days given by the 1 : 3 mortar specimens is very good, being 91 per cent of that given by test pieces made of standard Ottawa sand mortar.

PALAWAN

No concrete test specimens have been received from Palawan Province, and only three laboratory-made specimens were tested; these were made of Coron beach sand and gravel. Although the average compressive strength of the 1 : 3 mortar cylinders made of Coron beach sand is less than half of that shown by the 1 : 3 Ottawa sand test pieces, the compressive strength (2,443 pounds per square inch) of the 1 : 2 : 4 concrete made of the sand and gravel from Coron beach, used in connection with the construction of the Coron wharf, is very good. Inspection of the results in Table 2 obtained in testing Coron beach sands shows that whereas the average compressive strength of the 1 : 3 mortar specimens is 92 per cent of that given by the Ottawa sand test pieces, the tensile strength of the 1 : 3 Coron sand briquettes is only 44 per cent of that given by Ottawa sand briquettes, the age in all cases being 28 days. These results show that the time-honored tensile-strength test of Portland cement mortars is not always a true guide as to what may be expected from the same mortar when subjected to compression.

PAMPANGA

All results recorded under Pampanga in Table 8 were obtained from specimens made at the Bureau of Science of aggregates proposed for buildings at Camp Stotsenberg. All of the mixtures are 1 : 2 : 4 and give a mean compressive strength of 1,925 pounds per square inch, which is a little better than fair. Table 2 shows that the sand coming from Camp Stotsenberg is fine, and 1 : 3 mortar made therefrom gives only 75 per cent of the tensile strength of the 1 : 3 mortar briquettes made from standard Army sand composed of crushed quartz.

PANGASINAN

Very good results were obtained from concrete test specimens coming from Pangasinan. The values given by the 1 : 2 : 4 mixtures are uniform and average 1,628 pounds per square inch; those of cubes made of 1 : 2.5 : 5 concrete are erratic and average 1,238 pounds per square inch. The marked variability of strength in this series from a minimum of 730 to a maximum of 1,717 pounds per square inch is probably due to difference

in aggregate, though the difference between 1,268 and 730 pounds per square inch for specimens made from the same materials is more puzzling. As in other instances, the data here given lack certain value that they would have, had the district engineer included the source of the aggregate used in the concrete.

RIZAL

Compressive strength values given by concrete specimens from Rizal Province are variable; this variability, however, is almost entirely due to the different aggregates used. Specimens made of 1 : 3 : 6 concrete having ages between 28 and 31 days vary from 397 to 1,091 pounds per square inch, and average 825. The low values were obtained from test pieces containing Pasig River sand, and the high ones from specimens containing Mariquina River sand. The same difference is noted in the compressive strength obtained from the 1 : 2 : 4 specimens, though here an appreciable difference in age may have exerted some influence on the strength; the concrete specimens containing the soft, fine-grained Pasig River sand average 558 pounds per square inch at 28 days, and those containing the Mariquina River sand average 1,326 pounds, at 38 to 39 days. The use of Pasig River sand was abandoned in the last stages of the construction of Angono Bridge, because of the low results shown by the concrete containing this sand, and Mariquina sand was substituted with better results.

SAMAR

Most of the test specimens coming from Samar Province were marked 1 : 2 : 4, the rest being labeled 1 : 3 : 6 mixtures. By averaging the values given by the latter specimens, a compressive strength of 696 pounds per square inch is obtained; the age of these 1 : 3 : 6 test pieces varies from 28 to 34 days. Two low results, 496 and 388 pounds per square inch, characterize this series; the highest figure, 964 pounds, is good for this class of concrete. The specimens made of 1 : 2 : 4 concrete and aged 27 to 31 days gave extremely rambling results, varying from 330 to 2,168 pounds per square inch; this series shows an average compressive strength of 957 pounds per square inch. The striking irregularity in compressive strengths obtained from the 1 : 2 : 4 specimens made October 30 and December 16, 1914, from concrete used in the construction of Arapison Bridge is very likely due to carelessness; a variation of from 330 to 1,655 pounds per square inch could hardly be explained otherwise. It will be noted that most of the 1 : 2 : 4 specimens were con-

siderably older than 28 days at the time of the test. These irregularities in age, as in most of the other cases, were caused by delays in shipping the specimens to the testing laboratory in Manila. On acount of transportation difficulties it is not always possible to send specimens from unfavorably located districts promptly and have them in Manila in time for the 28-day test.

The 1 : 2 : 4 specimens aged 62 to 69 days average 1,298 pounds per square inch, and those aged from 74 to 91 days, only 913. These results are poor and are less than the value that a good grade of 1 : 2 : 4 concrete should give at 28 days. Some of the poor results obtained from Samar concrete are undoubtedly due to the use of the very fine beach sands characteristic of that province. Of the three sands tested two gave very unfavorable results, as Table 2 shows, and they should not be used as concrete aggregates. The compressive strength of the 1 : 3 mortar specimens in both of these instances is less than half that given by the corresponding Ottawa sand mortar test pieces. The third sand, which also came from the beach and which was tested November 24, 1914, although it gives excellent mortar strength values, shows a deficiency of fine grains and, therefore, makes a porous, permeable mortar that would allow the ingress of disintegrating substances.

SORSOGON

Although all of the specimens coming from Sorsogon were made of Salog River aggregate, and all, with the exception of those cast on November 9 and 15, 1915, were made of the same brand of cement, the compressive strengths show marked variation, the highest value being more than twice that of the lowest. The maximum and minimum are 961 and 432 pounds per square inch, respectively, and the average for 1 : 2 : 4 specimens aged 29 to 33 days is 668 pounds per square inch. The mean compressive strength is low and indicates a poor grade of concrete. Older specimens however show improvement in strength; the four test pieces aged 51 to 58 days average 974 pounds per square inch.

SURIGAO

Test pieces coming from Surigao were all made from 1 : 2 : 4 concrete used in the construction of Bilang-bilang wharf. The results are all poor. Specimens aged 21 to 29 days are fairly uniform in strength and average 602 pounds per square inch. The results given by the oldest, aged 35 to 37 days, are anomalous in that the older specimens are weaker than the younger

ones. Unquestionably, poor sand accounts largely for the unsatisfactory concrete strengths. Table 2 shows that the two Surigao sands tested are fine-grained, particularly the one coming from Surigao River. Specimens made of 1 : 3 Surigao River sand at 28 days give a compressive strength that is 46 per cent of that given by the corresponding Ottawa sand mortar test pieces. Sand from the wharf site gives a better value—74 per cent of that of the standard specimens. The latter sand was apparently used on the job, but the results are only one-third of what a good concrete should give.

TARLAC

Comparison of results obtained from concrete made in Tarlac is not very satisfactory on account of the appreciable differences in age of the test specimens. Some results are excellent, whereas others are only fair, and still others are incongruous. The great disagreement that exists between the average compressive strengths of 1 : 2 : 4 specimens made of concrete used in the piles of San Antonio Bridge is puzzling and is very likely due to carelessness in the manipulation of materials. Specimens cast May 8, 1913, and aged 25 days give the excellent average of 2,462 pounds per square inch, whereas another series of six specimens (date of manufacture not given) averages only 1,045 pounds per square inch at 31 days. It is likely that the proportioning of materials varied in these two cases and that a difference in cement content probably accounts for the difference in strength. Tarlac Province has an excellent building sand, which is commonly called Tarlac sand, and which on account of its light color makes it a suitable material for ornamental concrete. As Table 2 shows, the average compressive strength of 1 : 3 mortar specimens at 28 days is 1.6 times that given by the test pieces made of Ottawa sand. Tarlac sand is coarse and well graded, and contains very little quartz, the principal constituent being a clear, glassy, plagioclase feldspar. The Tarlac sand deposit is located along the Manila-Dagupan Railroad, and the sand has been tranpsorted by rail to Manila in fairly large quantities, for use in special work conducted by the Bureau of Science and the Bureau of Public Works.

TAYABAS

In general, tests of concrete made in Tayabas give unsatisfactory results. The compressive strength of the only 1: 2: 4 specimen is low and practically the same as that of the single 1 : 2.5 : 5 test piece coming from the same job. No information

is available with respect to the proportions used in the 58-day specimens made of concrete employed in the construction of the Atimonan Trade School. These particular test pieces give an extraordinary variation in compressive strength; the minimum and maximum values are 329 and 1,530 pounds, respectively. Concrete from Dumaca Bridge proportioned 1 : 3 : 6 gives fair values which average 573 pounds per square inch for specimens aged 28 or 29 days. Only one Tayabas sand was tested. It came from pit No. 1, Sariaya-Muntig River, and as Table 2 shows 1 : 3 mortar made therefrom gives excellent tensile and compressive strengths, which are appreciably higher than the corresponding ones obtained from Ottawa sand mortar test specimens.

ZAMBALES

Compressive strengths of concretes coming from Zambales Province are characterized by low, erratic averages. The specimens made of 1 : 2 : 4 concrete aged 28 days and used in the construction of Yamot Bridge give strengths that vary from 390 to 1,067 pounds per square inch. Test specimens made from 1 : 2 : 4 concrete employed in Candelaria Bridge give slightly better results than the 28-day cylinders averaging 822 pounds per square inch, and the 40 to 43-day cylinders averaging 1,101. The sands available for concrete construction in Zambales are very good as a whole, and some are excellent. All of them are clean and composed of hard grains, but the granulometric analysis in most cases shows a preponderance of fine grains. Nevertheless, the compressive strength of some of the 1 : 3 mortar specimens exceeds that shown by the corresponding Ottawa sand mortar cylinders. Test specimens made of sand from Lauis River give an average compressive strength at 28 days of 3,120 pounds per square inch, which is about 1.2 times that shown by Ottawa sand mortar test pieces. This sand apparently was used in the construction of Yamot Bridge, but the field tests of concrete containing it are far from satisfactory. Taking into consideration the good qualities possessed by Zambales sands in general, high-testing concrete ought to be the rule.

ZAMBOANGA

All of the test specimens coming from Zamboanga were made of the 1 : 2 : 4 concrete used in the construction of the Zamboanga Waterworks. The compressive strengths are fair. They are also uniform, which indicates a uniform method of measuring the cement and aggregates. The minimum and maximum re-

sults are 760 and 927 pounds per square inch, respectively, and the mean of the entire series is 831 pounds per square inch. These specimens range in age from 33 to 36 days. Two Zamboanga sands were tested at the Bureau of Science. Both are coarse, but they show strikingly different mortar-strength values. The beach sand composed of fairly hard grains yields a 1 : 3 mortar which at 28 days gives an ultimate compressive strength that is 90 per cent of that shown by the Ottawa sand test specimens. The river sand, containing soft grains in an advanced state of decomposition, gives a 1 : 3 mortar that is weak and at 28 days is only 46 per cent as strong as Ottawa sand mortar.

GENERAL DISCUSSION

Attention has already been called to the extraordinary variation in ultimate compressive strength of field concrete specimens made of the same materials, nominally proportioned alike, and differing only in being mixed and cast on different dates. Differences amounting to several hundred per cent characterize the results obtained from specimens from nearly all the provinces. With uniform materials, carefully proportioned and thoroughly mixed, such variation would be much reduced. Exceedingly crude methods of proportioning probably account for the extreme variations noted.

Considerable variation also exists in the compressive strengths obtained from specimens made from a single batch of concrete, as well as from specimens made of the same materials, proportioned alike, and made from various batches of concrete mixed on the same day. It will be noticed that most of the ultimate compressive strength values appearing in Table 8 are averages of two or more results obtained by rupturing two or more test specimens. It is the difference between results that have been so averaged that is being discussed at present. One would expect more or less close agreement of results obtained from specimens made from the same batch of concrete. However, the variation from the mean compressive strength in a given series in the field specimens is sometimes abnormally high, and in one case actually amounts to 135 per cent. Such extreme variation from a mean value in a series indicates either improper mixing or careless proportioning of materials; slovenly procedure during the molding of the test piece may also be a contributing cause. Any one, or two, or all three of these factors could cause erratic results. In Table 9 are recorded the maximum and minimum compressive strength values of concrete specimens in

TABLE 9.—*Maximum and minimum unit compressive-strength values of concrete specimens in typical series of tests.*

FIELD-MADE SPECIMENS.

Tracing No.	Structure in which concrete was used.	Concrete specimens cast.	Source of aggregate.		Test specimens preserved in—			Age when tested.	Results averaged or specimens broken.	Proportions by volume of cement, sand, and gravel.	Compressive strength of concrete, in pounds per square inch; ultimate stress.[a]			
			Sand.	Gravel.	Moist air.	Water.	Air.				Minimum value of series.	Maximum value of series.	Mean value of series.	Maximum variation from mean compressive strength.[a]
					Days.	*Days.*	*Days.*	*Days.*						*P. ct.*
1	Bridge 8.1, Guinobatan-Jovellar Road, Albay.	Apr. 15, 1915						42	[b]3	1:2:4	778	1,125	894	26
2	Bungol Bridge, Antique	Jan. 21, 1916	Beach near Bungol River.	Beach	7	2	29	38	[b]6	1:2:4	1,033	1,454	1,238	17
3	Obispo Bridge, Batangas	June 13, 1910						57	[b]3	1:3:6	977	1,259	1,097	15
4	Abatan Bridge, Bohol	Feb. 16, 1910			11		12	23	[b]3	1:2:4	566	734	668	15
5	Malolos Market, Bulacan, footings	Aug. 1, 1915	Pulilan River	Pulilan River				29	[b]6	1:3:6	440	682	594	26
6	Cañacao Bridge, Cavite, retaining walls.	Mar. 2, 1916	Mariquina River	Mariquina River	2	13	13	28	[c]3	1:1½:4½	400	875	609	44
7	Do	Mar. 8, 1916	do	do	2	13	13	28	[c]3	1:2:4	870	1,708	1,161	47
8	Naga River Bridge, Cebu	Nov. 16, 1909						30	[b]6	1:2:4	313	778	583	46
9	Magallanes Bridge, Cebu	Nov. 5, 1911						30	[b]12	1:2:4	2,191	3,205	2,659	21
10	Bridge piles, Ilocos Sur	Oct. 12, 1912						33	[b]3	1:2:4	1,073	1,620	1,384	22
11	San Juan Bridge, Laguna	Dec. 10, 1910						30	[b]3	1:2:4	1,781	1,917	1,841	4
12	Ormoc Market, Leyte	Sept. 13, 1915	Beach, fine	Ormoc River	1	14	13	29	[b]8	1:2:4	794	1,639	1,057	55
13	Masonic Temple, Manila	July 1915	Pasig River	Pasig River				28	[d]8	1:1½:5	305	617	484	37
14	Do	Aug. 4, 1915	do	do	1	19	16	36	[d]3	1:1¼:3½	1,142	1,298	1,199	8

15	Binondo Estero wall, Manila	Sept. 28, 1917						31	a 4	1:2:4	976	1,433	1,232	21
16	Jones Bridge, caissons, Manila	Sept. 3, 1917	Mariquina River	Mariquina River				28	c 6	1:3½:7	275	552	383	44
17	Tiguion Bridge 16.1, Gasan, Marinduque.	Aug. 9, 1915	Tiguion River	Beach				28	b 6	1:2:4	125	300	181	66
18	Do.	Sept. 26, 1915	do	do	1	13	17	31	b 8	1:2:4	109	306	251	62
19	Calmay Bridge, Pangasinan	Feb. 8, 1910						27	b 4	1:2:4	1,479	1,858	1,710	14
20	Bridge 9.6, Calbayog North and South Roads, Samar.	Mar. 5, 1916						90	b 3	1:2:4	389	805	603	37
21	Divisoria Bridge, piles, Tarlac	July 18, 1913						50	b 6	1:2:4	1,244	1,890	1,575	21
22	San Antonio Bridge, piles, Tarlac	May 8, 1913						25	b 5	1:2:4	2,221	2,645	2,462	10
23	Divisoria Bridge	1913						31	b 6	1:2:4	1,419	2,400	1,046	135
	LABORATORY-MADE SPECIMENS.													
24	Proposed for Santa Maria Bridge, Bulacan.	Nov. 23, 1917	Santa Maria River.	Santa Maria River.	28			28	c 3	1:2:4	1,222	1,460	1,328	10
25	Experimental mixture made in Bureau of Science of aggregates from Cebu, submitted by Bureau of Navigation.	Sept. 2, 1912	Mananga River	Mananga River	7		21	28	b 3	1:2:4	2,484	2,600	2,546	3
26	Experimental mixture made at the Bureau of Science of aggregates used in piles of Spillway, Gilbert Bridge, Ilocos Norte.	Oct. 1915	Laoag River	Laoag River	1		27	28	e 5	1:2:4	1,734	2,282	1,905	20
27	Pagsanjan water tank, Laguna	Dec. 8, 1918	Pagsanjan River	Pagsanjan River	28			28	b 3	1:2:4	2,130	2,290	2,197	4
28	Barugo School, Leyte	Sept. 22, 1915	Beach	Balaguhay River	1	27		28	c 3	1:2:5	1,834	2,156	1,989	8

[a] Mean maximum variation for field-made specimens, 34 per cent; for laboratory-made specimens, 9 per cent.
[b] Test specimens are 6-inch cubes.
[c] Test specimens are cylinders 8 inches in diameter and 16 inches high.
[d] Test specimens are cylinders 6 inches in diameter and 6 inches high.
[e] Test specimens are cylinders 3.568 inches in diameter and 7.136 inches high.

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typical series of tests, together with the maximum variation from the mean compressive strength. It is apparent that the grand mean value of 34 per cent obtained by averaging the individual maximum variations from the mean compressive strength of the field-made specimens is excessively high and could have been reduced considerably by more accurate and careful field work.

The maximum variation from the mean compressive strength of laboratory-made specimens is between 3 and 20 per cent and the grand mean variation is only 9 per cent, which is about one-fourth of that shown by the average results obtained from field-made specimens. By making smaller batches and giving greater attention to detail, the results from test specimens made in the laboratory will usually be more concordant. However, with due care, equally uniform results can be obtained from specimens made in the field.

Insufficient mixing that yields a nonuniform concrete; variation in the percentage of water; inaccuracies in proportioning cement, sand, and gravel; mistakes in marking test specimens; variation in storage conditions of the concrete test pieces—are all contributing factors to the erratic results already noted. However, there is still another factor which considerably affects the strength of concrete test specimens; namely, the manner in which the concrete is placed in the mold. It is certain that not a little of the variation in results is due to the different methods of molding the specimens comprised in a single series. Some of the specimens were made without tamping or spading and, of course, were honeycombed with air blebs. Others were tamped and consequently showed a compact texture. A uniform method of molding is conducive to uniform ultimate compressive strength but naturally cannot overcome the other disturbing factors which are the chief cause of irregular results. The more uniform the materials, the more carefully they are mixed; and the more uniformly and carefully the concrete is placed in the mold, the more uniform will be the ultimate compressive strengths given by the test specimens.

SUMMARY AND CONCLUSIONS

Ultimate compressive strength tests have been conducted on 1,677 concrete specimens more or less representative of concrete made in the Philippines during the decade from 1908 to 1918.

Laboratory-made concrete specimens proportioned 1 : 2 : 4 and aged 28 to 31 days give an average ultimate compressive strength

of 2,245 pounds per square inch, and field-made concrete test pieces marked 1 : 2 : 4 and aged 25 to 42 days give an average ultimate compressive strength of only 980 pounds per square inch. The lowest compressive strength, 177 pounds per square inch, given by 1 : 2 : 4 concrete was obtained from three specimens coming from Leyte.

Field specimens made of 1 : 2.5 : 5 concrete and aged 26 to 36 days average 944 pounds per square inch which, for all practical purposes, is the same as the mean compressive strength of concrete which is supposedly much richer. No 1: 2.5: 5 concrete mixture was made in the laboratory.

Test pieces made in the field of 1 : 3 : 6 concrete and aged 27 to 42 days give a mean ultimate compressive strength of 705 pounds per square inch, which compares favorably with the average results of 1,104 pounds per square inch given by the laboratory-made 1 : 3 : 6 concrete test pieces. The lowest compressive strength of 1 : 3 : 6 concrete recorded is 97 pounds per square inch and is given by a specimen coming from Capiz.

The differences between the average ultimate compressive strength of the 1 : 2 : 4, 1 : 2.5 : 5, and the 1 : 3 : 6 series of test specimens, respectively, are very slight and there are good reasons for suspecting that the procedure in proportioning the component cement, sand, and gravel was in the majority of the cases grossly inaccurate.

Aging beyond 28 days in most instances exercised an inconsiderable influence on the strength of the concrete specimens tested. Little if any increase in compressive strength accompanies increase in age of the greater part of the older concrete test pieces. In several cases an average decrease in compressive strength is characteristic of old test specimens.

Most of the low average ultimate compressive strengths may be traced to the use of fine sands, some may be attributed to faulty proportioning of cement, and in a few cases incomplete mixing of the batch accounts for low and erratic results. Careless molding of the test specimens in a few instances has been the cause of poor strength. Too much water and faulty storage of concrete undoubtedly have contributed not a little to the poor quality generally characteristic of field-made concrete in the Philippines, but in the absence of reliable data, it is impossible to estimate the influence exercised by these two factors.

Sands unsuitable for concrete work have been used throughout the Philippines and without subjecting them to a preliminary laboratory test. It was only after considerable actual con-

struction had taken place and samples of concrete had been tested, that the poorness of the sands was recognized. Usually a change in aggregate was then made. Such a procedure is to be deplored, and it often entails loss of time and money. A thorough laboratory examination of concrete aggregates is always a helpful guide to the engineer in selecting his material, and it is hoped that copious reliable data on Philippine concrete aggregates may be collected in the future.

Compressive strength results obtained from series of field specimens made from the same materials on the same day, and from the same batch of concrete, and averaged to give the values recorded in Table 8, generally show considerable variation. Laboratory-made specimens composed of the same materials, and molded from the same batch of concrete, are in much better agreement, and show only one-fourth of the average maximum variation from the mean that field-made specimens show.